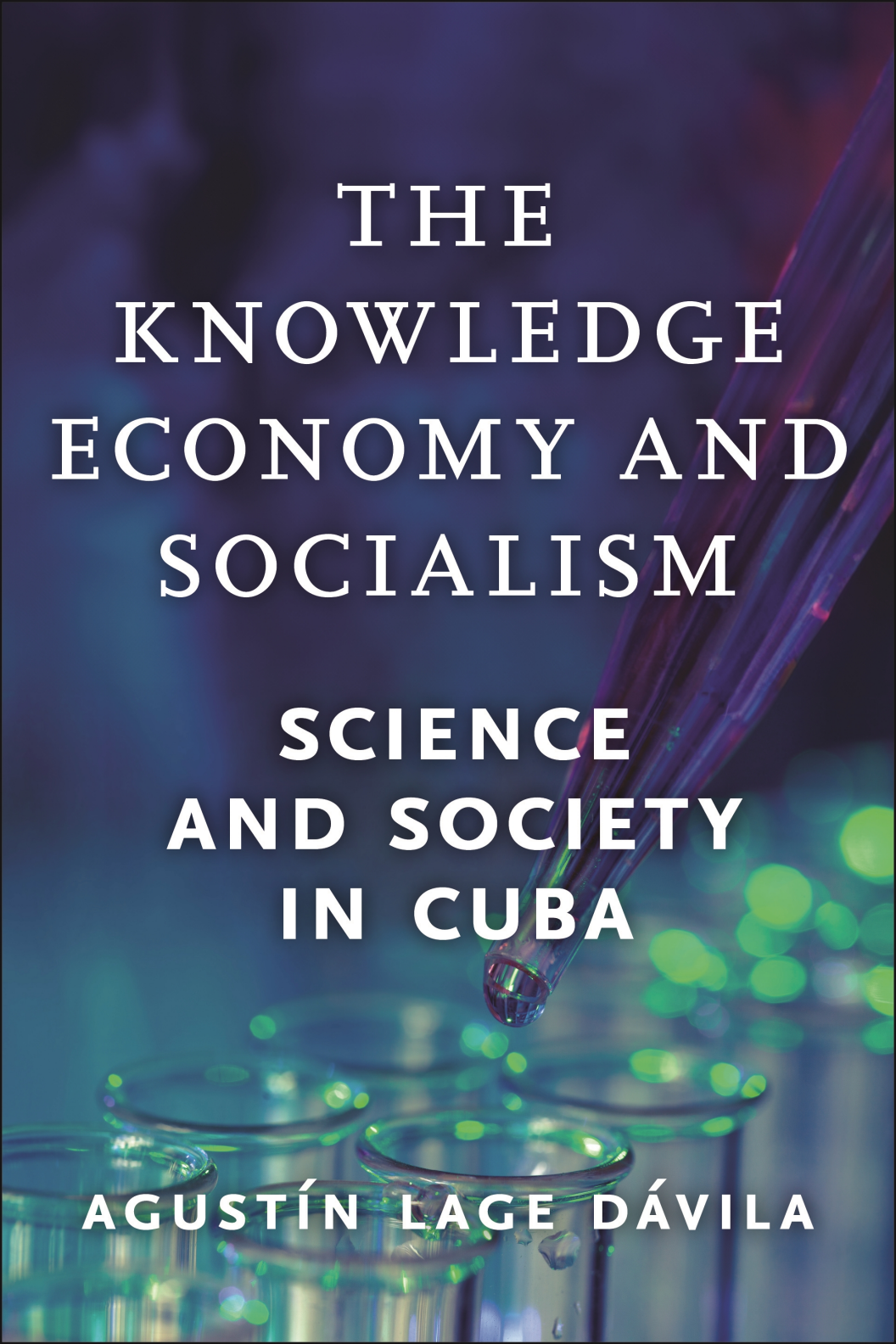

THE KNOWLEDGE ECONOMY AND SOCIALISM
SCIENCE AND SOCIETY IN CUBA
AGUSTÍN LAGE DÁVILA

THE KNOWLEDGE ECONOMY AND SOCIALISM

The Knowledge Economy and Socialism

Science and Society in Cuba

Agustín Lage

Translated by Mauricio Betancourt

MONTHLY REVIEW PRESS

New York

Copyright © 2024 by Monthly Review Press
All Rights Reserved

Library of Congress Cataloging-in-Publication data
available from the publisher

ISBN 978-1-68590-042-7 paperback
ISBN 978-1-68590-043-4 cloth

Typeset in Minion Pro

MONTHLY REVIEW PRESS, NEW YORK
monthlyreview.org

5 4 3 2 1

Contents

Acknowledgments | 7
Foreword to the Second Cuban Edition | 9
Foreword to the First Cuban Edition | 11

1. Introduction | 14
2. Property and Expropriation in the Knowledge Economy | 21
3. Science and Culture: The Cultural Roots of Productivity | 54
4. The Knowledge Economy and Socialism: Reflections from the Cuban Biotechnology Experience | 73
5. The Knowledge Economy and Socialism: Reflections from Yaguajay | 98
6. Connecting Science and Economy: The Levers of Socialism | 120
7. Knowledge, Society, and National Sovereignty in the Twenty-First Century| 150
8. The Functions of Science in the Cuban Economic Model | 171
9. The High-Technology Company and the Management of Discontinuities | 197
10. Management in the High-Technology Company | 216
11. The Knowledge Economy and Socialism: An Opportunity for Development | 236
12. The Knowledge Economy and Socialism: Cuban Questions | 246

Notes | 296
Index | 310

Acknowledgments

In a book, it is customary to say that there are many persons to thank and that it is impossible to mention them all. But in the case of this one, let me say wholeheartedly there are dozens. That's because this book's contents have come from hundreds of work sessions, Councils of the Direction of the Molecular Immunology Center (MIC), biotechnology directors' meetings, scientific councils, commercial meetings, bargaining sessions, discussions about territorial development in Yaguajay, and many other contexts, sometimes difficult, but always enriching. Over two decades (1995–2013), regularities began to emerge, and work processes were conceptualized, with participants having distinguished the essential from the epiphenomena.

How many colleagues [*compañeros/as*] contributed ideas? It is impossible to calculate. I took on the task of attempting a synthesis; therein lies the book's origin. Despite what some authors believe, elaborating ideas and interpretations only seems to be an individual process. Human thought always is social. Everyone who participated will know it when reading the book, see themselves reflected in it, and feel acknowledged, too: "I said that."

I want to express my gratitude to the directors of the *Revista*

Cuba Socialista, the theoretical publication of the Cuban Communist Party, where most of the articles that comprise this book were published and which enthusiastically welcomed each proposal, encouraging us to keep going. They allowed me to be in the trenches of the battle for ideas where we fight.

Professor Néstor del Prado, director of Editorial Academia, whom I remember as president of the University Student Federation in the turbulent 1970s, had the idea of compiling the articles into a book. Aldo Gutiérrez put all his professionalism and experience into the editing. I had the honor of having two other important supporters: Lila Castellanos, my wife, with her experience as editor of scientific journals and her vital militancy, who critiqued the content and its expression; and Laudelina Rodríguez, my collaborator in the trenches of the MIC direction, who contributed her energy, steadfastness, and commitment to every article that appeared, and then to the book. Everything else I would have to say in an acknowledgment—perhaps the most important—cannot be expressed in writing.

Foreword to the Second Cuban Edition

Words for the Reader

This book, a title of the Knowledge and Technology Management Enterprise's Academia Publishing [*Empresa de Gestión del Conocimiento y la Tecnología* (GECYT)], was to have a print run of six thousand copies. It ended up being seven thousand. We answered affirmatively without hesitation when asked if we agreed to take on the difference. The book was officially presented on October 16, 2013, in the opening session of the TECNOGEST 2013. By May 2014, all copies had been sold, with more requests from entrepreneurial organizations, universities, and research centers. We completed sales in less than seven months.

I had the honor of accompanying the author during five book presentations and dared to speak about him in his absence at the universities of Oriente and Matanzas, as well as at an international event held in Santiago de Cuba. Given that the book always aroused great interest, we decided to re-edit it with an additional chapter of questions, most of which were formulated by readers (who are anonymous) along with their corresponding answers.

We trust that this extended edition of *The Knowledge Economy and Socialism* fulfills expectations and becomes a useful tool for

us specialists for whom it is relevant or simply for any interested readers, thereby contributing to the indispensable endeavor of our Revolution's development.

— PROFESSOR NÉSTOR G. DEL PRADO ARZA
DIRECTOR, ACADEMIA PUBLISHING

Foreword to the First Cuban Edition

Academia Publishing, part of the Knowledge and Technology Management Enterprise in the Center of Molecular Immunology (CIM), manages knowledge and technology with a social vision. In developing the Human Capital NET and the New Enterprise Project, as in the biennial international event IBERGECYT, we from GECYT have an active collaborator in Dr. Agustín Lage Dávila. We realized his conference presentations and various written works had not been published in book form. Thus, in late 2012, we had the idea to publish a book focused on the knowledge economy and the construction of socialism. What resulted was a work relevant to the times we live in by an author with multidimensional knowledge, learning, experiences, and values.

I do not doubt that this book will spread good ideas, answer questions regarding inner bodily structures, and generate new questions. This conviction is based on the author's solid and sustained scientific training since his university days. I know his tireless struggle against cancer and his work with living organisms, from the micro- to the macroscopic. With more than two hundred publications on cancer and basic immunology, Agustín Lage Dávila (born 1949 in Havana) worked in Cuban biotechnology

as manager and director of the Center of Molecular Immunology (CIM). From his CIM experience in basic research, production, clinical assays, and the export of new anti-cancer drugs (protected by 757 international patents and introduced nationally and in highly developed countries), Lage has derived original theoretical contributions to the knowledge economy that transcend the boundaries of biotechnology.

As a member of the Cuban Parliament since 1993, his election as deputy of the municipality of Yaguajay allowed him to translate his ideas into a creative social experiment at the community level. This book compiles some of his analyses of the knowledge economy that he published over twelve years.

A PERSONAL HISTORICAL PREFERENCE

Let me tell you of a personal experience highlighting the importance of audacity in pursuing scientific and technological objectives. What is being done in biotechnology now has its roots in what was done in Cuba in computing decades ago, with the same revolutionary attitude to science and technology.

In 1982, as vice-president of the governing body of computer science, I participated in a meeting of representatives of socialist governments. There, I disagreed with two pronouncements that I considered mistaken. First, personal computers, then a novelty, were considered a symbol of capitalism, alien to a socialist society. I argued against this; I will spare you the details. Second, it was proposed that by 1990 we should manufacture the large computers the powerful North already had as the zero series in 1980. I argued, "How is it possible that we plan ten years ahead in a field where the renewal span is eighteen months? And if, on top of this, we take into account that our Achilles' heel is the introduction of science and technological achievements, then it would surely take more than ten years; thus our achievements will keep being born old."

When returning and confessing my alleged excesses to Dr. Carlos Rafael Rodríguez and listening to his wise reasoning, I felt

the relief of not having acted on a youthful impulse. Remember that the one closest to my age was eleven years older; the one presiding over the meeting was forty years old.

In the book, Agustín Lage Dávila delves into his topic, knowledge economy and socialism, and its complex theoretical framework and elaborates on the work of the organizations tasked with turning scientific research into products with use- and exchange-value. The book's main lesson is how to think, plan, organize, and start a coherent and sustainable organizational system utilizing multi-sectorial collaboration, including the contributions of technological institutes, vocational schools, and universities.

I am confident that even those who desire the failure of Cuban socialism will not abandon the book after reading the Introduction. Champions of "improved capitalism," an oxymoron because it is not possible to improve a system that metastasizes like aggressive cancer, this book will be bad news. If they are enlightened and knowledgeable enemies of socialism, they will have to approach this book with respect. It would not surprise me even if some reconsider their prejudices or ways of thinking.

Editorial Academia is pleased to present this contribution to updating Cuba's economic model. We are grateful to the author for allowing us to turn his valuable work into a book. Thanks also to the editor, the author's assistant, the designer, and all those who were part of this birth.

Thanks in advance to you, the readers, and hopefully, students of this work. You are the *raison d'être* for this book.

— PROFESSOR NÉSTOR G. DEL PRADO ARZA

CHAPTER 1

Introduction

This book compiles articles published between 1994 and 2013. They were not written with the idea of being turned into a book, but rather as an attempt to capture a conceptual elaboration that crystallized during those two decades, based on practical experience in different moments, but that, taken now as a whole, are seen as aligned around the topic of science's role in the construction of socialism.

Writing them at the time (and sharing them in this volume) is an unavoidable duty. This is because Cuban scientists, especially those involved in the biotechnology sector, have lived a unique experience, very endogenous (as is the Cuban Revolution itself), with features and contexts that are not repeated elsewhere and whose conception and interpretations are not to be found in any outside reference. We must produce the results ourselves.

When attempting this, it becomes evident that, although the experience of biotechnology exhibits features of that scientific and technical field, the essential processes underlying this experience pertain to science's connections with production and the economy, and to a great extent, they are generalizable to diverse sectors of high technology, such as informatics, communications, and

new materials, among others. This creates the duty of capturing and systematizing what we have learned, separating the essences of conjunctural phenomena, and putting these intellectual tools at the disposal of those who will come next to continue and perfect (including criticizing) what is constructed in this stage.

The idea of socialism was born and was always linked to the aspiration of scientific and technological progress. An intellectual heir to the cult of human rationality that emerged in the eighteenth century with the Enlightenment, "scientific socialism" contains the idea that human beings can, from an intelligent understanding of the laws of history, deduce the path that society ought to take and actively guide it in that direction. In Marx's analysis, the crisis of the capitalist system is a consequence of the fact that this system becomes an obstacle to the development of productive forces, that is, to techno-scientific progress.

The Soviet Union was the first country to realize those ideas practically, and for a while, it succeeded. While the capitalist world was stuck in the great economic depression of 1930, the USSR accelerated industrialization. Between 1929 and 1940, industrial production grew threefold and Soviet participation in world manufacturing went from 5 percent to 18 percent.[1] Starting from an agrarian and technically backward country, the technological development attained by the industrialization efforts of the 1930s allowed the Soviet Union to create productive bases to resist and overcome the test of the Great Patriotic War in 1945, rapidly recover from the immense destruction wrought by the war, and emerge as a world scientific and industrial power that aroused the world's admiration by placing the first human being in the cosmos in 1961.

The victory of socialism in the USSR had a leading component in the ties between science and society. We Cubans drank from that experience in our young Revolution. Then, in the 1980s, the problems that created the interruption of the European socialist experience and the dissolution of the USSR in 1991 affected the links between science and society because of the failure to adapt

to the changes in the productive forces (and in the organization of production) of the Third Scientific Revolution, derived from automation, communication, and informatics technologies. Despite having a fourth of the physicists and half of the world's engineers, GDP growth in the USSR (which had attained a 5.7 percent annual rate in the 1950s) started to decrease, falling to 2 percent from 1980 to 1985.[2]

For communists, the relationships between science and society are not trivial. They have always been at the very center of victories and setbacks. How do these relationships occur when the socialist revolution occurs in a small underdeveloped country? How do these relationships occur when the context is no longer that of endogenous industrialization and the domestic markets of the twentieth century but rather that of twenty-first-century globalization and the knowledge economy? This is where the Cuban experience has something to say.

In 1960s Cuba, a country with a 24 percent illiteracy rate, Fidel Castro stated, "The future of Cuba necessarily has to be a future of men [*sic*] of science."[3] In 1993, the rock bottom year of the economic crisis of the special period, he reiterated his vision, stating that science and scientific productions should someday occupy first place in the national economy. In the first years of the twenty-first century, biotechnological products and those of the pharmaceutical industry (a typical high technology sector) reached the second material exports tier in the Cuban economy. In 2009, an editorial in *Nature* recognized Cuban biotechnology as "the developing world's most established biotechnology industry, which has grown rapidly even though it eschewed the venture-capital funding model that rich countries consider a prerequisite."[4]

What happened during those decades? What did we Cubans do right and wrong? What did we learn that may prove useful for facing the future's ever-novel challenges? Answering these questions entails going beyond the anecdotal, the figures, and the specific stories of institutions and products, to locate the underlying regularities and essential phenomena. We must initiate this

analysis ourselves, those of us who have participated in the process in those stages. Those who come later will have the advantage of seeing this experience from the lens of time. We have the advantage of seeing it from within. History will then make the synthesis.

Addressing the duty of "comprehending and communicating," we started "groping-writing" the articles that constitute the chapters of this book. The second chapter, "Property and Expropriation in the Knowledge Economy," was written in the late 1990s, in the heyday of neoliberal ideology in Latin America. It sought to polemicize, with a vision of the knowledge economy as a solely technological phenomenon, exposing the hidden face, now with new features, of the old phenomenon of capitalist appropriation of others' labor.[5]

The third chapter, "Science and Culture: The Cultural Roots of Productivity," situates scientific development within the larger effort of developing culture in Cuban society and identifies the channels by which both tasks fertilize each other.[6] The fourth chapter, "The Knowledge Economy and Socialism: Reflections from the Cuban Biotechnology Experience," describes the experience of Cuba's biotechnology sector and discovers the underlying connecting processes between science and the economy.[7] The construction of these connections between science and the economy creates positive discontinuity rather than the linear accumulation of scientific results in funded institutes. In 2004, there was an intense debate, sometimes between extreme positions. Today this controversy has been finally settled by the Revolution's Guidelines of Economic and Social Policy, approved by the Sixth Congress of the Communist Party in 2012, but it might be useful to review the article as it appeared then.

Through the analysis of the experience of Cuban biotechnology, the reader will encounter five main theses. First, the successful experience of Cuban biotechnology, albeit frequently communicated and understood in its medical and scientific impacts, is essentially socioeconomic, one of constructing links between science and economy. This is the main process. Second, what is

happening in the Cuban biotechnology sector is the expression of a broader phenomenon connected to the emergence of a knowledge economy that is mainly expressed in high-technology sectors, such as biotechnology, microelectronics, telecommunications, and software, but that progressively penetrates all the branches of the economy. Third, the increasing role of knowledge in the economy makes the internal contradictions of the capitalist mode of production more evident and acute. Socialism is far better prepared to assume this new stage of development of the productive forces.

Fourth, by increasingly inserting itself within the economic systems, science assumes a dual role. It can be a threat to development and social justice aspirations, as capitalism tries to privatize knowledge, but it also can be an instrument of liberation and development insofar as the attempt to privatize knowledge makes capitalism's contradictions more evident. Fifth, like all the aspects pertaining to the construction of socialism, this connection between science and the economy cannot be left to blind mechanisms but requires conscious guiding. The experience of Cuban biotechnology since the 1980s is also an experience of such conscious guidance, in which Fidel Castro's leadership was fundamental.

This book's fifth chapter, "The Knowledge Economy and Socialism: Reflections from Yaguajay," analyzes the struggle for development in a small rural municipality.[8] In the decades when he participated in the development of biotechnology, the author also served as Deputy of the National Assembly of Popular Power of the Yaguajay municipality. The pleasant surprise that emerged from this experience was that the role of knowledge management and the fundamental processes in the development of a high-tech industry and in the local development of an agricultural municipality have a lot in common.

The chapters on biotechnology and Yaguajay identify the advantages of socialism regarding economic development based on knowledge. I also tried to capture this in the sixth chapter, based on the article "The Levers of Socialism."[9] Taken together, the two

chapters confront efforts to characterize the dissolution of the European socialist bloc as a failure of the fundamental postulates of socialism. Historical processes require some time to be analyzed with perspective. Not enough time has elapsed yet vis-à-vis this topic, but it is already clear that the solution to humanity's pressing global problems must come through socialism.

The seventh chapter, "Knowledge, Society, and National Sovereignty in the Twenty-First Century," addresses the connection between the knowledge economy and the defense of national sovereignty.[10] Combating the attempt to dilute national sovereignty within homogenizing cultural globalization and denationalizing science is one of the great issues of our time. For us, the defense of national sovereignty is a principle beyond dispute. But we serve it better if we can transmit to future generations why national sovereignty makes human development possible.

The eighth chapter, "The Functions of Science in the Cuban Economic Model," provides insights into the integration of science into the unique Cuban economic model. Chapter 9, "The High-Technology Company and Management of Discontinuities," was originally published in 2012 in *Revista Temas*.[11] It was written after the discussion and approval of the Revolution's Economic and Social Policy Guidelines,[12] which summoned us to update our economic model. The guidelines set out tasks of enormous scope for all sectors of society. Science is part of it, and it is necessary to move forward in elaborating and specifying its functions in constructing and defending our socialist project.

The next two chapters are steps toward those specifications. "Management in the High-Technology Company" (chapter 10) is a detailed look at the state-socialist high-technology company. The next chapter (11), "The Knowledge Economy and Socialism: An Opportunity for Development," continues with that topic through the micro lens of the directive processes of a high-technology enterprise.

The final, and longest, chapter (12), gives my responses to questions that were asked in various discussions of the first Cuban

edition of the book, which were held with both specialized groups and the general public. I chose fifteen questions, to reflect the themes of the book and those deemed of special importance for Cuban society and the growing knowledge economy.

Each chapter can be read separately, with relative independence from one another. But each elaborates on the previous one. Because the chapters originated as articles published at different moments and in different journals (most of them in *Revista Cuba Socialista*), some ideas are repeated.

Seen as a whole, what you are going to read describes and analyzes a social experience of constructing links among science, economy, and culture, a creative experience of which we Cubans can feel justly proud. But you will not find a superficial triumphalism that dodges the analysis of problems. The perils and challenges are noted in each topic, for they constitute part of what must be comprehended and transmitted. The perception of these perils and challenges reinforces the sense of responsibility that we all must do things well and not deviate from our course.

The conviction that we can win predominates in this complex interaction between accomplishments and perils. Let us say it clearly in case anyone needs such clarification: this is a book written by a communist, and it is written to defend socialism. Those antagonistic to this goal can stop reading now.

CHAPTER 2

Property and Expropriation in the Knowledge Economy

"All rogues are stupid; the good guys are those who win in the long run."

—José Martí

Consciousness about and the literature on the new position of knowledge (and the organized generation of knowledge) in economic systems are relatively recent.[1] There has been little time to accumulate empirical data and extract conclusions. Moreover, the data that can be collected today on the relationships between scientific research and economy in different countries are probably of limited utility, given that what we are witnessing about knowledge's role in the economy is not an incremental change but a discontinuity. And discontinuities are not easily explored by extrapolating into past tendencies.

Let us then accept from the outset that the road traveled does not suffice to offer data and conclusions, but it does start to construct a vision, which for being early may be imprecise, but also may be opportune. On the other hand, constructing this vision from the perspective of the Cuban experience is a singular opportunity.

There are abundant efforts to study the integration of science and the economy (national systems of innovation, technological parks, and so forth), but all within the market economies' context; that is, perhaps different in their forms of organization and management, but very similar in their property forms.

This uniformity has biased the analysis, for the vast majority of studies on the topic concentrate on discussion of management forms of productive resources (knowledge in this case) and ignore the problem of appropriation when it is precisely the property regime that essentially distinguishes socioeconomic systems".

One of the few places where an experience of scientific, technical, and economic development based on the knowledge economy can be analyzed in the context of a socialist system and from the perspective of its actors' social commitment is Cuba. Add to this that the Cuban experience occurs in the context of an underdeveloped economy in a so-called Third World country, and it will be clearly seen that the analysis of this experience can be relevant (and useful) for most of humanity. This justifies the attempt and excuses the limitations of this book.

WHAT IS THE KNOWLEDGE ECONOMY?

The term "knowledge economy" seeks to capture a set of phenomena that denote the increasing importance of knowledge in the functioning and development of the systems producing goods and services. In recent years, a substantial literature on the subject has accumulated. I will cite two well-known thinkers on the future of economies. In *Powershift*, Alvin Toffler declares that ". . . because it reduces the need for raw materials, labor, time, space, and capital, knowledge becomes the central resource of the advanced economy,"[2] while Peter Drucker concludes that "the industries that have moved into the center of the economy in the last forty years have as their business the production and distribution of knowledge and information rather than the production and distribution of objects."[3]

That knowledge is important for production is not a new concept: technology, experience, and information are all necessary to extract oil, produce sugar, and offer tourism services. The novelty lies in expanding industries and entire branches of the economy, where knowledge is the "limiting resource" and not land, raw materials, or even capital.

Consider, as extreme situations, the extractive industries (oil, for example) at one pole and software production at the opposite pole. In extractive industries like oil and mining, it is obvious that the limiting factor is the availability of raw materials. If they are abundant, the necessary capital and technologies can be procured. But even when raw materials are plentiful, geological, technological, and bargaining knowledge, and worker training, all have an increasing role as catalyzers of the process that turns a natural resource into an economic resource that can be realized in the market.

In the software industry, raw materials do not exist; everything is knowledge. The production and service sectors are intermediate in the balance between the material and intangible components, as determinants of the result. But it is precisely those sectors, wherein knowledge has a determining role, that have expanded the most in the industrialized countries in recent years: software, microelectronics, computing, telecommunications, pharmaceuticals, biotechnology, the aerospace industry, polymers and high-tech plastics, new materials, fine chemicals, and so on.

Between 1976 and 1996, the portion of world trade classifiable as "high technology products" doubled (from 11 percent to 22 percent), while the portion corresponding to primary products shrank from 34 percent to 13 percent.[4]

We see the symptoms of this transformation in the following:

- The increase in workers who work only with information.
- The increase in the value of knowledge is incorporated into cost and price structures.
- The exponential growth of the patents' stock and litigation on patents.

- Competition for product differentiation rather than for scale and price.
- The lessening of products' obsolescence time, which displaces competitiveness toward innovation capacity.
- The increase in economic transactions on tangible assets.

And many other symptoms hint at the essential process underlying the transformation of knowledge in the critical limiting resource of economic development. Access to this resource begins to be a new polarizing factor in the world economy. Industrialized countries, with less than 20 percent of the world's population, realize more than 80 percent of the global investment in research and development, publish more than 85 percent of scientific articles, and hold more than 90 percent of patents. In the North, the fraction of the population involved in science and technology is estimated at 0.2 percent, while in the South, it is less than 0.05 percent.[5]

THE KNOWLEDGE RESOURCE: SIMILAR AND DIFFERENT

As an economic resource, knowledge has features similar to other resources, like raw materials, labor power, and capital goods. Knowledge has a cost, and it is not low. If it is taken into account that, in many developed countries, the educational system absorbs approximately 10 percent of the Gross Domestic Product (GDP), that companies spend another 5 percent of the GDP on training, and that another 3 percent to 5 percent is used for research and development, most advanced economies today invest one-fifth of their GDP in producing and disseminating knowledge. This is more than what these same economies invest in traditional capital formation.[6] The cost of knowledge is transferred to the cost and price of products.

To the extent that knowledge has become limiting and has ceased to be a freely accessible element of "externality," companies must pay for it, either for its acquisition (patents, technology

transfers) or its generation. This built-in knowledge is a source of value, for it is an expression of work. For Marx, the value of a commodity emerges only from labor; only labor power can generate value. But in this process, both "immediate labor," which occurs during manufacture, and "general labor," which is incorporated into value through knowledge and technology, occur. Marx defines it thus: "Universal labour is all scientific work, all discovery and invention."[7]

But knowledge as a resource also has peculiarities that differentiate it from other resources. Land, natural resources, labor power, and capital are finite. Sooner or later, they are exhausted. On the contrary, knowledge is infinitely expandable; you can always generate more. Knowledge is not "spent." Two companies cannot use the same plot, nor the same brigade of laborers, simultaneously, but they can use the same knowledge simultaneously.

Some have taken this idea to the extreme, saying that knowledge is accessible but cannot be appropriated. As we will see later, this extrapolation is false. One of present-day capitalism's most complex and dangerous processes is its efforts to privatize knowledge. Although knowledge is indeed harder to privatize than land and capital goods, therein lies the opportunity. Knowledge is rarely applicable directly or immediately. Its application often requires new knowledge linked to the context, national or local, in which it is used. Last, knowledge depreciates very rapidly when replaced by new knowledge. It cannot be stored.

These last two features imply that the advantages or disadvantages of knowledge's role in the economy depend less on the amount of knowledge possessed than on the capacity to generate new knowledge rapidly and continuously. The heart of the problem is the system of science and technological innovation. Like any other resource, knowledge has a "productivity," a yield of return. There are no measurements for this, not even a theory, but there is the intuition that the effort of generating knowledge produces different economic returns in different contexts. The most cited example is the comparison for the period after the 1950s,

between the remarkable production of scientific knowledge in England with a limited translation into industrial competitiveness and Japan's economic rise, which was not mainly based on the production of new knowledge.[8]

When we view knowledge as a productive resource, we see that having this resource is one thing and investing it properly to obtain an economic return is another. This immediately leads to the idea that having a science and technological innovation system is one thing, and intelligently and efficaciously connecting it to the productive apparatus is another. Science is, obviously, a necessary condition but not a sufficient one.

KNOWLEDGE AS AN ECONOMIC RESOURCE: THE FALLACY OF CIRCULATION

The qualitative changes in knowledge functions within economic systems occur simultaneously in three realms: knowledge generation, knowledge circulation, and knowledge appropriation and its valorization via economic transactions

Naïvely or intentionally, the literature concentrates on the volume and speed of knowledge circulation. It seems as if, to spur economic development, it was enough to connect to the Internet with sufficient bandwidth. We are indeed witnessing an unprecedented explosion of information: there are more than two hundred million personal computers worldwide; every year, a million patents are registered, and two million scientific articles are published. It has been estimated that every day seven million new websites appear. Someone calculated that, at the current publication rate, if all published books were placed in a line, one would need to move at 93 mph to keep up with the end of the line.[9]

There is a lot of knowledge in circulation, and there will be more. But the circulation of knowledge, just as commodities, does not create value. The essential changes lie in the fact that knowledge is being generated differently and is appropriated differently. Knowledge generation changed over the twentieth century.

Humanity always has sought to know, but science, as a conscious, organized, and systematic activity to obtain new, generalizable knowledge, is not as old in the history of humanity. In fact, it was an activity of dilettantes until the eighteenth century. Only in the nineteenth century did the profession of scientific researcher emerge, initially closely linked to universities.[10]

In the twentieth century, three important changes occurred. The first was the emergence of scientific research institutes established by nation-states outside the university system. This happened for the first time in Germany in 1911.[11] From then on, systems of non-teaching scientific institutions grew and developed, differing in their organization and size, but always under state financing and control. The production of knowledge thus operated as part of social expenditure, creating a context of knowledge and cadres from which companies profited without paying, as if they were economic externalities.

The second change is the companies' increasing investment in funding scientific research through different contract modalities or alliances with academic or university institutions. Since the 1970s, more than 50 percent of non-military scientific activity in the main industrialized countries has been financed by private industry.

The third change, which overlaps in time with the second one and is probably the most important, is the increasing internalization of the research-development activity as part of the production and services companies' working content. In the United States, in 1920, there were some three hundred laboratories in corporations; in 1960, there were 5,400. Establishing these labs is an acknowledgment that material production cannot advance without integrating an organized process of knowledge production.[12]

The pharmaceutical industry may serve to illustrate this tendency. Its research and development expenses went from 12 percent to 22 percent of its turnover in the past seventeen years. This entails an annual expense of more than US$30 billion. Near the end of the twentieth century, new companies emerged where knowledge generation is an intrinsic and main activity.

When knowledge becomes the limiting resource, companies assume the responsibility of generating a larger share, and their competitiveness depends on it. This occurs asynchronously in different sectors of the economy, with results more visible in the high-technology sectors where the following features can be distinguished:

- High research and development costs.
- Supply of specialized, sometimes unique products and services.
- Competition for "product differentiation" rather than for scale and price.
- Frequent negotiations on "intangible assets" (patents, brands, technologies).
- Wide use of patent protections.
- Acceptance of risk as constitutive of business management.
- Use of highly qualified labor power.
- Human resources irreplaceable, treated like an asset and not as an expense.

It is not hard to see that such companies progressively adopt the features that have always characterized scientific research institutes: future vision, unpredictable results, and highly qualified human resources. This tendency, along with the increasing tendency of scientific centers to care about and address the economic impact of their research, creates a situation where the boundaries between research companies and economically impactful scientific centers become ever more blurred. Efforts to artificially maintain this boundary are useless and destined to fail, if not today, soon.

Biotechnological companies can serve as case studies of this tendency. More than thirty years after the emergence of the first biotechnological companies in the United States and Europe, more than 80 percent still operate on negative cash flows and are not self-financed through their sales. This is a consequence of their investing more money in research and development than they earn. How do they do it? Basically, at the expense of venture

capital investments or the sale of shares on the stock exchange, selling perceptions and promises, which in practice, becomes a way of financing research and development at the expense of future earnings rather than at the expense of prior earnings, as other industries do.

THE PROPERTY QUESTION: THE REAL PROBLEM

The shrinking of the links between the generation of knowledge and the production of goods and services until subsuming (at least partially) scientific research in business management is an objective and unstoppable process that results from the degree of development of the productive forces. This is not intrinsically negative for the future of humanity nor for the higher aspiration of social justice. Confronting this tendency would mean confronting a false problem, which is the same as avoiding the real one. The real and main problem is not production but appropriation. Production occurs one way or another. The question is, who owns what is produced? And who owns the means of production?

Ever since humanity abandoned the primitive community and generated productive surpluses beyond the subsistence level, the property question has been raised, especially property over the means of production. The battles around property have gone through different stages and diverse forms, concentrating on those factors of production that are central, meager, and limiting in each epoch. Thus, slavery legitimized some people's property over others, considering the slave and his labor power a means of production.

Later, property in land was at the heart of the battle. It was not always so. There were entire centuries when land was in excess relative to the human population and its capacity to exploit it. These were "common lands." When land became limited, it was appropriated by the powerful classes. Then came capital and capital goods, the factories and machinery that have determined economic performance and competitiveness since the Industrial Revolution.

Conflicts over property have accompanied humanity for more than three thousand years. From this point of view, it is not surprising that the transformation of knowledge into the "limiting resource" for producing goods and services is accompanied, under capitalism, by an aggressive attempt at knowledge appropriation and privatization. The question "Who owns knowledge?" seems absurd at first glance. It clashes with ethics and culture. If anything is entirely a social product, it is knowledge, dependent upon culture and precedent.

But it is precisely the attempt to privatize knowledge that we are witnessing as a reaction of the capitalist system to its new function in limiting economic resources. What is taking place is a change in how the individual appropriation of the results of social labor occurs. This is one of the most dangerous phenomena of the still-young twenty-first century. In addition, the processes of appropriation are not always transparent. We scientists have three urgent tasks before us vis-à-vis this issue:

1. To discover how the private appropriation of knowledge occurs. As will be seen, there are four: intellectual property protection, internalization of scientific knowledge in big industrial organizations, speculation on regulations, and "brain drain."
2. To make an ethical judgment of this process to generate a collective consciousness on the illegitimacy of such appropriation.
3. To build alternatives to the current processes, to "expropriate the expropriators." This is the most complex task.

INTELLECTUAL PROPERTY: TRIPS AND THE PRIMARY ACCUMULATION OF KNOWLEDGE

The first and most evident (albeit not the only) form of knowledge privatization is intellectual property (an intrinsically contradictory term), expressed in science and technology mainly through patents. Each year, more than a million patents are registered. The universal imposition of the protection of intellectual property is

part of the GATT (General Agreement on Tariff and Trade) agreements, which gave rise to the World Trade Organization in 1995.[13] In actuality, intellectual property was little addressed in the GATT negotiations from its genesis in 1947 until they were included in the Uruguay Round's Agenda in 1986, mainly under pressure from the big pharmaceutical companies.

A patent is a monopoly right of commercialization (and exclusion of third parties from commercialization) granted by the state over a given time to someone who has made an "invention." The invention must have practical and non-trivial utility and stem from prior knowledge. Patent laws have existed for a long time, and for a while, they worked well. But, as the generation of new, immediately applicable knowledge became a quotidian event in many sectors of production and services, the number of registered patents multiplied, competition forced the premature grant of patents for inventions that lacked practical utility, the boundaries between the obvious and non-obvious blurred or became arbitrary, and litigation multiplied.

The shift of research funding to the private sector encouraged universities and public institutes to protect virtually everything through patents. Patent costs and litigation placed the power of intellectual property in the hands of those with more resources to pay them. Lawyers' costs to obtain a patent reached $10,000, and litigation costs no less than $1.5 million.[14] Today, multinational companies have thousands of patents.

The situation has reached absurd extremes with the controversy over the patentability of genes. In 1991, the National Institutes of Health of the United States were at the center of the polemic for registering their first patent for expressed gene fragments (EST: Expressed Sequence Tags), whose biological function and practical application were unknown.[15] In 1998, the European Directive on Biotechnology (Directive 98/44 of the European Parliament) established the patentability of any genetic information material. Today, more than six thousand patents for genes have been granted in the United States, of which more than one thousand correspond

to human genes. It is said that there are more than half a million that are pending analysis.

The system, in addition to being unfair, is dysfunctional. The acquisition of new knowledge is always based on previous knowledge. Today, intellectual property is claimed for scientific results that just a few years ago would have been published in open access. Thus, any researcher will increasingly find that many pieces of knowledge they need for a project are already the property of someone with the right to deny their use or demand payment. The transaction costs may be enormous and dissuasive, and the whole system could hinder scientific knowledge. In medicine, the ethical implications of this problem are even more acute. The concession of monopoly rights on scientific discoveries unavoidably restricts their use and increases the costs. The international controversies about access to medications for treating AIDS have shown the tragic side of knowledge privatization.

The logic of patents lies in the search for a return rate on the investment (in this case, research), and is a consequence of applying the laws of the market to scientific research. Yet, in the production of knowledge (unlike in the production of material objects), the "inventor" only carries out the final stretch of a long creative process that depends on society as a whole. The ethical conflict pertains not only to the property of knowledge but also to the whole property system over the means of production and the private appropriation of socially-generated products. But, in the case of knowledge, this contradiction is all the more evident.

We are facing a situation analogous to what Marx describes as the "primary accumulation of capital" and defines as "the historical process of divorcing the producer from the means of production."[16] In *Capital*, Marx describes how, when farmland became a limiting resource, the rural population of eighteenth-century England, which used it as a commons, was violently expropriated. The appropriation was established in a series of Acts of Parliament beginning in 1604 that enclosed open fields and common land in the country, creating legal property rights to land

previously considered common. The Agreement on Trade-Related Intellectual Property (TRIPS), approved in 1994 and protected by the World Trade Organization, today operates as a sort of Bill for Enclosure of Knowledge that leads to violent appropriation and to a kind of primary accumulation of knowledge, hitherto a common fruit of the culture and creative intellect of many people.

THE ECONOMY OF SCALE OF SCIENTIFIC RESEARCH AND THE ENLARGED REPRODUCTION OF KNOWLEDGE

The laws of protection of intellectual property, in their different variants, constitute a very visible form of privatization of knowledge, albeit not the only one. The appearance of organizations of scientific research within the industry creates—independently of intellectual property—another mechanism by establishing the conditions for internalizing past labor under capital. Let us try to dissect this phenomenon a little further.

Scientific research is seen by many as an act of individual creativity, whereby certain talented and well-read individuals find relevant pieces of information within the enormous and confusing quantity of data offered by the real world. This is an intuitive, essentially probabilistic process that has no methodologies. The scientific method relates to how relevant questions are answered but not to how they are formulated. At a certain moment of maturity of a given branch of science or technology (this varies across fields), an enormous amount of relevant scientific questions, valid experimental proceedings, and other important data to be obtained, accumulates. This is far beyond the practical capacity of a scientific researcher. Thus, a branch of knowledge becomes ripe for standardization.

Let us take the example of pharmacological research to discover new drugs. Once it is known that a given molecular receptor in a cell is important for a given function, the next step is to standardize a sensitive, specific, and cheap assay method and employ it to assess as many molecules as possible, with or without the

help of computing simulation procedures. Once a molecule with agonistic or antagonistic effects is available, an analogous series is constructed, and the relationship between chemical structure and biological activity is explored using standardized procedures. Then, the most attractive candidates are selected for toxicological and pharmacological studies (also standardized) and later for even more standardized clinical trials with their various phases. All this can be the work of hundreds of scientists for many years, costing hundreds of millions of dollars. Similar examples can be found in almost every branch of science and technology. Thus, the economy of scale of scientific research starts to take hold: big and well-equipped labs in the industries, many researchers, and standardized procedures. The individual scientist loses control over the process and even becomes disposable. The company, with its resources—that is, capital—assumes the job.

Here we can also find an analogy between capitalism's beginnings and the Industrial Revolution. When manufacturing emerged as a special form of labor organization that replaced craftsmanship, and through the systematic use of machinery, workers lost their technical independence, becoming part of the organization of production. The factory and its machinery internalized part of the immediate labor, and the process definitively severed workers from the products of their labor, limiting them to selling a "commodity": their labor power. This occurred two hundred years ago with so-called immediate labor realized during production. Now, we witness an analogous phenomenon, but this time with "general labor," which incorporates value into the product through knowledge, inventions, and technologies from past efforts. Science has been transformed into capital. After that, in these organizations, knowledge reproduces itself in a sort of "enlarged reproduction of knowledge," where, similar to the way Marx defined it for capital, "Every accumulation becomes the means of new accumulation."[17]

It would be absurd to oppose the organization of scientific research through big collectives with their efficient procedures, just as the Luddites' opposition to machinery as a technical

phenomenon was in 1812. The problem is not in the mode of production but in the regime of appropriation. For instance, the big, state-owned Cuban biotechnology centers function differently from capitalist ones. We shall return to this topic.

REGULATIONS' SPECULATION

Regulations, or "technical barriers to trade," have not ceased to grow over the last thirty years. According to the World Trade Organization, a technical barrier is a document that establishes a product's characteristics or those pertaining to its production processes and methods, including applicable administrative provisions to which compliance is mandatory. This phenomenon is particularly evident in the pharmaceutical and biotechnological industries, where the costs of making products and processes comply with regulatory standards are enormous. A similar phenomenon has started to weigh heavily on the food industry.

It is not a question of criticizing the regulatory standards needed to make high-quality products and protect consumers. The problem starts when regulatory standards leave the necessary quality requirements behind, when they are artificially inflated and turned into non-tariff, protectionist mechanisms in favor of large companies. Under these conditions, satisfying regulatory requirements generates enormous fixed costs with two effects. First, they take profitability from small- or medium-sized companies with insufficient turnover value to absorb these fixed costs within their profits. Second, these costs are transmitted to prices, limiting, in the case of medications, for instance, their acquisition by those who need them, thus reducing their impact vis-à-vis the health problems they are supposed to solve. If pharmaceutical products were assessed for their population-level impact on health, it would be evident that with insufficient regulation, there would be little impact because of insufficient quality. With excessive regulation, there would again be little impact, given the high cost and poor accessibility of products.

At the extreme, there are situations close to absurdity, as with

the poliomyelitis vaccine, an efficient product that has been able to stop—and is close to eradicating—a terrible disease. All experts recognize that this vaccine exists because it was developed in the 1950s; had it been discovered today, with today's regulatory standards, it would never have been approved.

This problem, like every problem that depends on finding the right balance between inconvenient extremes, has very complex aspects. And in the face of such complexity, many prefer not to address it and to continue the constantly increasing regulatory requirements, perhaps expecting that, as in *The Emperor's New Clothes* fable, someone will someday expose the absurdity and say, "The emperor is naked."

The protectionist character of some of the current trade barriers is an object of much debate today, even within the WTO. But this is not the aspect I want to address. The reason for including this section in an analysis of the appropriation of knowledge as an economic resource is this: the successful management of the regulatory context has itself turned into a technology, supported by literally thousands of regulatory documents that are applied in different combinations, in each situation, and whose complete domination, besides being impossible, is not even a guarantee for success, for the interpretation of current regulations itself is subject to perceptions that vary with the standards that each industrial sector creates.

The necessary knowledge to face the technical barriers is far from public; it accumulates in ever fewer hands and is partly commercialized through hundreds of consulting agencies, training and education centers, and contract research organizations (CROs). Large pharmaceutical companies' competitive advantage comes from their know-how in managing the regulatory context. In fact, the complexity of the problem dissuades many small companies, which prefer not to attempt to control the research-production-marketing cycle and instead negotiate licenses with the large companies. The value of the knowledge required to address regulatory barriers is part of what these companies receive in exchange for their product in these transactions.

Thus, this know-how adds value to the product and creates competitive advantages. But, unlike the knowledge added to a product by a scientific discovery or an innovation in production, the value created for the domination of the regulatory context is, at least partially, speculative value derived from the practical knowledge to solve problems that have been artificially created.

The process looks a lot like speculative growth in stock value, which is based on artificially created perceptions and is actually tradable for some time, or like the stimulus to consumption from commodities that sell an "image." The net result is a great flow of money in exchange for little added value, which generates more concentration of capacities and continues in that direction until such concentration becomes an obstacle to the whole system's productivity, even in the richest countries. "Find a need and get paid to meet it" is reiterated in several texts on commercial strategies. "Invent a need and get paid to meet it" seems to be the variant that applies to our topic.

"BRAIN DRAIN": A STEP BACK TOWARD THE PROPERTY OVER PEOPLE

The transformation of knowledge into a limiting resource in ever more production and service sectors does not occur in a vacuum; it takes place in a historical context characterized by the power of imperialism and neoliberal globalization. When Marx wrote *Capital*, the capitalist contradiction between the social character of production and the private character of appropriation was expressed so acutely that the matter of "agonistic capitalism" began to be discussed. One hundred years later, Che Guevara warned that this judgment was premature: "Let us be careful with statements like this: 'agonistic.' A mature man can no longer undergo physiological changes, but he is not agonizing. The capitalist system reaches its full maturity with imperialism, but even this has not made the most of its possibilities at the present time and still has great vitality." He went on to state that the vision of the relationship

between the bourgeoisie and the proletariat as a fundamental class relationship "corresponds to the classical conception of Marx, who had not foreseen Imperialism," and to insist that ". . . Imperialism's tendency is to make the workers who subsist on crumbs participate in the exploitation of other peoples."[18]

In globalization, no problem can be analyzed apart from its global relationships, and certainly not the functions of knowledge in the economy. We are witnessing accelerated wealth concentration and marginalization of people that is evident by whichever indicators are utilized to measure it: GDP distribution, food consumption, energy consumption, or others. The relationship between the income of the richest 20 percent and the poorest 20 percent of the world's population passed from 30:1 in 1960 to 61:1 in 1991 and to 82:1 in 1995; the tendency continues.[19] In 1965, the mean rent per inhabitant for the seven richest countries was twenty times higher than that of the seven poorest ones; in 1995, it was already thirty-nine times higher.[20]

When occurring internationally, this process is even crueler and more dangerous than within nations, given that the scarce legal basis that establishes states' responsibilities vis-à-vis all their citizens becomes diluted at the international scale. No one in Washington is responsible for what happens in Chiapas. The concentrating tendency in knowledge production is even more acute. Industrialized countries account for more than 90 percent of all scientific production.

We have already analyzed how socially produced knowledge is privatized in favor of industrialized countries' capital. The point of this section is how the scarce investment in knowledge production made in the Global South is also privatized, in favor of the industrialized economies. An important part of this knowledge investment lies in the formation of scientific and technical cadres. They are bearers of the knowledge resource created through social investment. It seems this is not appropriable unless the appropriation of people occurs. This is precisely what happens.

More than one million professionals from Latin America and

the Caribbean work as emigrants in the United States, England, and Canada. If the cost of educating a professional is estimated at $30,000, this emigration signifies a South-to-North transfer of $35 billion, equivalent to ten years of investment in science and technology. That is several times more than all Inter-American Development Bank aid for the region's scientific development. Twenty-three percent of all PhDs working in the United States come from other countries, and this figure reaches 40 percent in computing. Approximately a third of all scientists trained in the third world do not work in their countries, and it is currently estimated that a little more than half of those who travel to North America or Europe to get a doctorate do not return. These numbers speak for themselves, but that is not all. It should also be kept in mind that even if the emigration of scientists and technologists started spontaneously, spurred by the prospect of improved living and working conditions, the promotion of this emigration has become an official state policy in many Northern countries in recent years, with incentives especially designed to that end. This migration thus becomes an efficient mechanism to expropriate from the poorest countries the scarce progress they have been able to make on knowledge generation. These migrant scientists and technologists generate a significant amount of patents; hence even the theory of intellectual property as an investment return mechanism becomes contradictory because the economic outcome does not return to the countries where the investment in training those scientists was made.

This tendency, combined with the growing internalization of scientific labor inside large private organizations with a high concentration of capital, leaves emigrants (like workers in relation to their labor power) no choice but to sell their capacity to generate knowledge in exchange for a wage that equals the reproduction costs of this qualified power and that has nothing to do with the value created by their scientific labor, which belongs to others.

Here we conclude the discussion of the forms of private

knowledge appropriation seen as an economic resource. Let us see some additional consequences.

A GLOBAL PROBLEM

The term "global problems" has been increasingly used to describe population growth, scarce energy resources, migration, environmental pollution, food production limitations, violence, drug trafficking, and the AIDS pandemic. All countries feel their impact, and their solution cannot be undertaken in isolation by any single nation.

Let us add to this list the geographical concentration of science and see why it is unfavorable for everyone, even for the richest countries. Surprisingly, this phenomenon is excluded from the inventory of global problems, given that the polarization of science is not only in itself a problem but also one that limits the application of viable solutions to other problems. The polarization of scientific activity threatens to exclude 80 percent of humanity from knowledge.

Science and knowledge are practically the same problem. In today's world, the capacity to use knowledge is ever more linked to the capacity to generate it. Technology transfer models are less and less functional. Given the speed at which new technologies emerge and are renewed, any transfer has to be very creative. Without the capacity to generate knowledge, it will not be possible to assimilate it either.

Private appropriation, the concentration of accumulated knowledge, and the capacity to concentrate the creation of new knowledge in fewer hands is a matter of tremendous ethical and political implications. But l will leave that aspect of the problem aside momentarily and note that this also threatens the efficiency and productivity of scientific creation on a global scale. Let us see why.

- Science rapidly transforms into a constituent of general knowledge, a structured procedure to comprehend the real world

through acquisition, analysis, and organized data verification. This tendency would be very beneficial if it were massively available to people. The concentration of science in a few groups will have as negative an effect as limiting the ability to read and write to a few.

- Science benefits from a diversity of perspectives. This diversity is profoundly ingrained in the social character of scientific practice and is related to the intrinsic diversity of societies. The concentration of science reduces this diversity and interferes with the essential substitution of paradigms.
- Science advances not only through the emergence of wholly new pieces of knowledge but also through the recombination of existing knowledge. This is directly proportional to the number of scientific collectives pursuing different objectives, as is the intensity of communications (the connectivity of the scientific network). Genetics has long ago discovered the advantages of recombination and polymorphism; the organization of science still does not seem to have gotten the message. Science, especially in biology, must consider the enormous diversity of biological systems in the world, particularly in the South. The concentration of biotechnology introduces the risk of biasing research toward model systems instead of real ones.

The list could be even longer. Suffice it to say that the current concentrative tendency of scientific practice is detrimental to productivity at the global scale, not only in the disadvantaged countries, where the consequences of the private appropriation of knowledge should be added, and so it starts to become an obstacle. Its effects are not completely visible yet. Still, in the last decade of the twentieth century, any scientific project was based in prior knowledge that mostly belonged to the public domain. Bear in mind that the explosion in property protection for virtually any new piece of knowledge started in the 1980s. From now on, and increasingly so, we will witness the clash of any new project against dozens of patents and technologies owned by others, with ample

exclusionary rights vis-à-vis third parties, even from the research stage. The contradiction between the private appropriation of knowledge and the intrinsically social character of knowledge production will obstruct the development of productive forces.

Marx, with his revolutionary sensitivity, hoped for the end of capitalism for justice reasons, but, at the same time, with his scientific rigor, he foresaw the end of capitalism not because of its injustices but because of the limitations that the contradictions of its property regime would impose on economic development. The increasing transformation of knowledge into a limiting resource of goods and services productions sharpens these contradictions.

SCIENCE AND ECONOMIC DEVELOPMENT: ASSOCIATION OR CAUSALITY?

Scientific research is the organized process of generating new, verifiable, and generalizable knowledge about objective reality. Scientific research within a given moment and social context can be measured by different indicators (amount of researchers, institutions, research and development expenses, patents, publications, and others). Indicators are in themselves controversial, for they measure different aspects of a complex phenomenon that cannot be captured by a single figure. However, with any given pair of indicators with which to attempt to graph the relationship between scientific activity and economic development (GDP versus the number of scientists; industrial production versus publications; per capita energy consumption versus patents; or any other combination), a close relationship between indicators will be found.

More science and innovation are accomplished in the richest countries. This is so evident that the next question could seem banal: is scientific activity the cause of economic development or its distal consequence? As will be seen, the answer to this question is not evident, and its consequences are not trivial.

Developed countries invest between 2 percent and 2.5 percent of their GDP in research and development. This percentage,

calculated against a GDP of trillions, such as in the United States, presupposes a great deal of money that can finance a lot of scientific activity. The economy's effect on research is direct, almost linear, but the effect of research on the economy does not have the same relationship of immediacy and proportionality. At the macro (country) level, some published data indicate great differences among countries in knowledge production. For example, in the second half of the twentieth century, England's indicators of scientific activity intensity were superior to those of Germany and Japan. The economic growth indicators behaved the other way around. Yet the topic has not been sufficiently studied at that level, much less the micro level, by economic sector and company.

Causal relationships are difficult to establish in the social sciences. However, two large categories of scientific activity exist: one precedes economic development and directly propels; the other follows economic development and has a parasitic relationship to it, or at least its effects on the economy become so indirect in the long run that the evidence is lost. Such distinction would be of great practical importance, as all preceding reasoning about the function of knowledge within economic systems and its appropriation are mainly applied to the first kind of scientific activity and innovation, which we could call "propelling science," and not to the second one, which we identify as "propelled science."

But we lack useful indicators to make this classification. Neither the volume of scientists, expenditures, nor the production of publications are adequate indicators to analyze scientific activity according to its economic impact, and much less to predict it. Perhaps the number of patents being exploited (not those registered), the number of scientists working in industrial organizations, the funding by industry of research and development, the structure of human resources in the productive sector, and the portion of foreign trade corresponding to products protected by patents or those produced with their own new technologies, are better indicators—not only for the study of knowledge generation but also for where it is generated, how it is used, and their performance.

Trying to discover and measure not all scientific activity but only that fraction that propels the economy would be very difficult. But the analysis should be attempted. Not everything correlated with GDP is a cause of development. Going down this path of reasoning, one could reach "perfume's absurdity." Cosmetics sales also are associated with GDP, as is per capita energy consumption, but the implications of each are obviously very different. What portion of our science is energy, and which is but perfume for the economy? It is to be expected that this kind of analysis will have enormous practical implications. This double relationship between science and economy, in which science can be the cause or effect of economic development or a mixture of both, makes it very difficult to evaluate the economic fruitfulness of current scientific research in a particular place and time.

Rich countries have an accumulated advantage largely derived from the pillage of poor countries, a consequence of yesterday's colonialism and today's unequal exchange relationships. This larger resource availability for scientific investment translates into high indicators of the general scientific activity (number of scientists per inhabitant, institutions, GDP percentage invested in science, publications), which are the figures we read in the studies on the topic. These are indicators of the economy's effect on science but not necessarily of science's effect on the economy.

However, much is to be discovered about the relationships between knowledge management and economic development. We, the less affluent nations, cannot seek to attain the "macro" indicator in research funding (as "propelled science"); but we can attempt to discover and reinforce the connecting mechanisms between science (in this case as "propelling science") and the economy. The relations of production under socialism make this possible. Biotechnology in Cuba is an example of how it can be done.

EXPROPRIATE THE EXPROPRIATORS

Social justice and the construction of socialism are important in

the economic struggle, which will increasingly develop in a globalized economy based on knowledge. The conditions of production, the property relationships of knowledge, and their impact on international economic relationships will be at the center of any country's strategy that undertakes this journey and, of course, in our own.

From a certain point of view, the processes described above could be seen as threats whereby the private appropriation of socially generated knowledge is attempted, and capital concentration also translates into knowledge concentration. These are indeed threats, but from another perspective displacing the main levers of productivity and competitiveness to the field of knowledge can be an opportunity. Let us see why.

- In the first place, more than the prolongation of a past tendency, such displacement is a discontinuity. And discontinuities are always spaces for creativity and innovative strategies. Every discontinuity creates an opportunity (for those knowing how to take advantage).
- Second, the mechanisms of knowledge appropriation are relatively new in historical time, and their juridical bases are insufficiently grounded, let alone accepted.
- Third, the analogies we have described between knowledge and other production resources (material resources, capital, labor power) are just that, analogies, not identities. Thus, knowledge, as a productive resource, has characteristics that make its appropriation and concentration in a few hands much harder. Capitalism will attempt it, but it is up to us to prevent it.

What is to be done? The author will not attempt (nor would the reader accept) to propose strategies from a first and basic approach to the topic, much less formulate simplified recipes. But some rough ideas about the road to take are emerging and are worth noting. There will be two big simultaneous tasks: criticizing reality and building the alternative. The first without the second would

not be a struggle but a complaint. The second, without the first, can collide with huge obstacles. And let us not confuse the target to be criticized: not the use of knowledge in producing goods and services, the transactions of intangible assets, research and development in industries, or the emergence of companies that base their economic management on knowledge production. This is an objective consequence of developing the productive forces and let it be welcomed.

The problem, as has been the case for the last three thousand years, is property. The first task is to denounce the appropriation of knowledge and reveal its mechanisms—the most evident and the most subtle. The struggle against appropriation starts with creating an ethical consciousness of the illegitimacy of such property. This ethical consciousness will sooner rather than later transform into juridical ordering. We third-world countries lost this battle at the General Agreement on Tariffs and Trade (GATT) bargaining table.[21] We should return to this battle. Everything begins by building a consensus, on a world scale, on the implicit immorality of using knowledge to widen the inequalities among human beings. The ethical judgment will create the bases for its juridical expression, which, in turn, will legitimize the political pressure. Expropriation will not occur without some form of violence expressed through new forms of political pressure.

BUILDING THE ALTERNATIVE

Cuba has traveled down this road and its analyzable social experiences. Let us begin on January 15, 1960, when Fidel Castro said to a country that then had an almost 30 percent illiteracy rate, "The Future of Cuba has to be necessarily a future of men [*sic*] of science."[22]

Four topics immediately emerge when reviewing the experience of these years: the people who create knowledge, the organization of knowledge's "productive apparatus," international collaboration, and the economic realization of knowledge. First, the people.

Producing anything, including knowledge, requires many high-quality producers. The effort of training human resources for science and technology in the 1960s and 1970s produced more than 1.8 professionals dedicated to research and development for every 1,000 inhabitants, a figure close to that of Europe and four times the average of Latin America. And scientific professionals are just a component of the system. They are joined by hundreds of thousands of workers linked to massive innovations. This is very important. It is true that quantity is not everything and that there are important qualitative factors, but it is also true that there exists a mass effect. Innovation is better when there are many innovators.

And here lies one of our competitive advantages, perhaps the most important. Human resources for research and development are not abundant. This helps explain why some industrialized countries promote the immigration of scientists and engineers from the South. This topic would require a study of its own. But we already can see that capitalism's proletarianization of scientific knowledge and the alienation of scientific creation from the ownership of the results, as well as the use of competition and other market mechanisms to regulate investment in knowledge, begins to erode the science and innovation systems of the industrialized capitalist nations.

In Cuba, the high numbers of scientists and technicians who are well-trained, motivated, and committed to the social project of which they are part constitute a powerful force for reversing the worldwide tendency to concentrate both the generation and use of knowledge. The scientists are endowed not only with technical skills but also knowledge and social consciousness and are motivated not only because they produce knowledge but because that knowledge will be used to foster equality and not to widen injustice. This explains the successful resistance to the enormous pressures exerted by the "brain drain."

Second, there is the design of knowledge's productive apparatus: the collectives and institutions. The elimination of borders between what in the 1960s were funded scientific centers and the economic

system's productive enterprises is an objective and well-managed process that reflects in the organizational plane the integration of knowledge as a chief resource in producing goods and services. On the one hand, research-development systems within industries have been organized and expanded, as with the Ministry of Basic Industries system and the military industries; on the other hand, research-production centers have been created from scientific collectives, as with the scientific pole of biotechnology.[23] Scientists, scientific organizations, technicians, innovators, and research and development collectives are the main actors in the expropriation of the expropriators in the knowledge field.

Third, access to worldwide flows of creation and circulation of knowledge and the connections (not only electronic) with the world's scientific community requires intense and intelligent handling of international collaboration. Except for a few countries (China, India, Brazil), most third-world countries are, like Cuba, small. The viability of small nations in today's interconnected world cannot be based on self-sufficiency (which is impossible, if only because of size) but rather on being incorporated into the complex web of world relationships—in this case, vis-à-vis knowledge generation—and especially with the capacity to creatively manage the inevitable contradiction between worldwide connections and the preservation of national interests.

International scientific cooperation, managed by several international organizations and industrialized countries, rests on inappropriate foundations. It presupposes that developing countries follow the same road as industrialized nations, only with a two-hundred-year lag. Therefore, it is sufficient to train cadres and reproduce organizational forms. This is not true. The countries of the Global South are not following the same path of technological development as those of the North. They are following a divergent road that leads elsewhere.

- When Europe and North America were building their embryonic scientific systems they also had little development but were

always the leaders. There was no other "first world." Scientific research was about innovation, leaving little space for imitation, the search for external recognition, or sensitivity to external pressures.
- At the beginning of the twentieth century, scientific research was not as directly linked to production and commerce as it is today.
- Modern science emerged in today's industrialized countries in an atmosphere of free exchange and publication of results. There was nothing similar to the current system of intellectual property protection.
- During its first days, scientific research was an individual task that did not require complex institutions, support services, or organizational resources, as it does now. Any international cooperation scheme for scientific-technical development that ignores these realities is doomed to failure. And this is what is happening.
- Cooperation programs offer grants when what is needed are joint projects.
- Cooperation programs focus on individuals' development when the appropriate objective is to develop institutions or scientific collectives.
- Cooperation programs are frequently focused on academic exchanges, but the correct objective would be to link academic and entrepreneurial components.
- This list could be longer, but it suffices to say that any serious effort to revert the concentrative tendency of scientific activity would entail a profound revision of North-South international collaboration.

Another important aspect is so-called South-South cooperation. A lot has been written on this topic, and I do not intend to focus on it. I mention it only to affirm that one cannot do without it. There will not be efficient North-South cooperation without simultaneous South-South cooperation. North-South cooperation

cannot consist only of philanthropic aid; given the growing relationship between science and the economy, it has to increasingly become a negotiation. International cooperation can be either the path to the distribution of knowledge and development or the path to dependency and brain drain.

THE WHOLE CYCLE: RESOURCES-KNOWLEDGE-RESOURCES

Last, there is the topic of the economic realization of knowledge, which completes and validates all of the above. Suppose knowledge is an economic resource. In that case, it should have, as with other resources, a closed cycle that is completed when it is realized through economic transactions and generates new resources for its reproduction and the benefit of society. Thus, no matter how deep and exhaustive, analyzing how knowledge is generated and how to generate more is only half of the problem. The other half is how that knowledge is captured and incorporated into negotiable assets. In small countries like Cuba, this mainly means knowledge realizable in international negotiations.

The concentration and appropriation of knowledge occur globally and internationally. The struggle for expropriating the expropriators must be fought on the same plane. It is not about ignoring the need to organize transactions among Cuban scientific centers and companies; this is a matter of procedure, not an objective. The real aim is to prepare Cuban industry to become internationally competitive. The Cuban economy's high-tech technology sectors (we are seeing this with biotechnology) have a high research-development fixed cost, which is hardly recoverable in the small domestic market. Thus, even if exceptions exist, there is a general link between high technology and an orientation to exports. This orientation must include export to industrialized countries at high prices. Export pricing must reflect the economic levels in those countries, built with the surplus extracted from the Global South and through unequal exchange. When we access those countries' markets this way, wealth concentration starts to

be reversed. This can occur as long as the knowledge incorporated to value comes from us and is not manufactured *por maquila.*[24]

One of globalization's current problems is that the third world's national component of export diminishes. This tendency will be hard to reverse with the material component of production, but for products and services with a high content of knowledge forming their price, it could be possible. Thus, when applied to knowledge, the concept of the whole cycle leads us to analyze how knowledge is incorporated into negotiable assets. The first path is knowledge incorporated into the product itself (and its price). This is what occurs with recombinant proteins and other biotechnological products. This requires research-production-commercialization centers that guide the process without sterile fragmentation within inter-institutional borders.

The enormous potential of this organizational form is one of the main things we learned in the 1990s. This also requires intellectual property, an instrument that will enter a world-scale crisis sooner or later but whose use remains essential. Cuba currently operates more than one thousand patents in the biotechnology sector. It is "knowledge property," but in different hands and with a different social meaning. Its meaning cannot be dissociated from the social (state) character of the property of scientific centers that own those patents. Preserving the social property character of institutions has been the most important directive in every negotiation.

On the other hand, the centers' structure, organization, and experience contain and protect incorporated knowledge independently of patents. There are no patents covering the ultra-micro-analytic (SUMA) system nor the Center of Research and Neurological Restoration's (CIREN) services, but the experience and knowledge contained in these organizations render the product unique and non-copiable. This gives added value, and we must find ever more efficient forms of realizing this value in commercial transactions with industrialized countries. In addition, it is necessary to systematize and structure the analysis of the experience acquired by this kind of negotiation within our

particular conditions and identify the regularities that can be extrapolated.

The second path is complex negotiations about knowledge itself, not incorporated into products yet. The practical examples of these years are patents' non-exclusive licenses, technology transfer negotiations, and risk investment agreements for joint product development.

In all these cases, the main negotiable asset is knowledge. Throughout these negotiations, knowledge becomes value. Obviously, in many instances, the best option is to incorporate knowledge into products and obtain the highest value when commercializing the product. But what happens with oil frequently happens with knowledge, too: it is there, but investment is needed to "extract" it; that is, to turn it into something directly negotiable. In the case of oil, that investment is extraction technology. A biotechnological product can take the form of the resources needed to complete clinical assays in Cuba and abroad, overcome technical-regulatory barriers, and increase production.

There are other important differences: the value of mineral resources is well-maintained, while oil's value is known by everyone. There are even world prices. But knowledge depreciates rapidly. Its value depends on perceptions, risk estimation, and bargaining abilities. The speed of knowledge depreciation impels us to rush through the bargaining process. The second difference, subjectivity in assigning value, tells us we should negotiate cautiously and without haste. What is to be done? Obviously, train many good cadres to conduct this process and build a frame of bargaining directives to organize it.

Besides the general characteristics of negotiations on the value of knowledge, we see that there are special sources of value for certain products as, for example, the following two:

1. When the product or service ends up being applied in the health system, the validation given by its massive application, at the

population scale, as in Cuba, could become a high-value asset if we can extract and organize the information.
2. When the product is related to a biodiversity resource of ours, which entails a differentiation and competitive advantage factor. The 1992 Rio de Janeiro Convention established that biodiversity resources are the sovereign property of nations. It was a political victory that will remain incomplete until we find the practical means to use that right. This forces us to constantly review what we do in the endemic genomes and natural product study fields.

Conclusions still are few, while the tasks are many. Knowledge transformation into an economic resource, especially its commercial realization, is complex. The knowledge economy is being born, and a long road of diverse strategies, of trial and error, will be necessary. Today's accelerated and intensive knowledge economy requires more flexibility and less standardization than the epoch of large-scale industrial productions. This will demand a high degree of operative decision decentralization toward emerging high-tech companies.

But, again, and perhaps this is the central idea of this chapter: we cannot confuse management with property. Others at other latitudes understood the dynamizing process and decentralization as privatization and the state's withdrawal from the economy. If this is about taking the opportunity created by the knowledge economy to defend socioeconomic development that differs from neoliberal globalization—and we are engaged in that battle—there cannot be confusion or concessions around the topic of property. And all the alternatives we explore (varied, flexible, decentralized) also must be linked to defending social property over the means of production (whether factories or knowledge) and the socialist distribution of the results.

CHAPTER 3

Science and Culture: The Cultural Roots of Productivity

Science and culture have been two central fronts of the work and struggle of the Cuban Revolution. We Cubans have fought to develop both. This has not been a spontaneous process; there has been strategy, system design, organized effort, and efficacy. One can speak of efficacy because a profound transition has occurred through a complex mix of successes and errors throughout the decades. Cuba has gone from a country where 24 percent were illiterate and 45 percent attained only elementary education to a nation with an average eleventh-grade educational level. Cuba has the world's highest density of art instructors and a ratio of scientists to the general population close to that of the most industrialized nations. Cuban science has produced and exported biotechnological products, many of them unique, and all in an incredibly short historical time.[1]

How is scientific development related to the cultural context? Can we describe the relationship in a structured and systematic way that enhances their interactions? Our cultural specifics are clear, but could our specificities in science also be? These are the questions that prompted the reflections that follow. They are written in the direct and affirmative language of propositions (almost

in a clinical language) because they seek to begin, not to conclude, discussions. From afar, the propositions may look like a building under construction, full of scaffoldings and noise, incomplete parts and disarrayed pieces, and not like a beautiful edifice surrounded by gardens. But I think it can be useful to consider the questions this way, which is what matters, at least for now. The basic idea is that, besides developing science and culture, we must work for their articulation, which requires strategy, system design, and organized effort. Efficacy in this integrative process can tremendously enhance what we have done so far.

SCIENCE AND CULTURE AS FORMS OF KNOWLEDGE

The so-called empirical sciences are a form of knowing reality. Artistic culture is another one. Empirical sciences are rational, systematic, exact, and verifiable. Those are its virtues. But they are analytical, partial, and reductionist knowledge. Those are its limitations.[2] Artistic culture also reflects reality but is expressed through images, a conjunction of experience, imagination, vision, and the ability to realize non-analytic interpretations.

There is a method for acquiring knowledge in the empirical sciences, whose structure we can identify and describe. It operates through a cycle that repeats itself continuously, starting from identifying a problem or puzzle and formulating a hypothesis for solving it. The scientist's hypothesis is always an instrument: a formulation of the possible solution to the problem in clear, measurable, and refutable terms. Predictions, extracted from a hypothesis that is assumed true, are then operationalized and made into measurable variables through an experiment. Thus, the scientist prepares the experiment, isolates these variables from others that may create noise, performs measurements and evaluates the data, usually through statistical procedures, to decide whether it verifies or negates the initial hypothesis and whether it must be kept or changed to generate new predictions. This is where a cycle closes, and the next one begins.

We cannot yet describe with such precision the cognitive process by which culture, and especially artistic culture, captures reality. (This does not mean that such a process does not exist.) We know it intends to capture the whole of reality without reducing it to its components through an approach more synthetic than analytical. But we know very little. The creative process has eluded analysis by being as complex as the reality it tries to capture.

This dichotomy in cognitive approaches toward reality is relatively recent. Note, for example, that since ancient times, painting was considered a discipline of cumulative knowledge (as we see today in science) that advanced in its approach to depicting reality through successive discoveries. Still, during the Renaissance, the sciences and the arts were not seen as intellectually separate activities, and many creators moved from one field to another. (Da Vinci is the best-known figure, but he is not the only one.) The term "art" was applied to painting, sculpture, and technology. The scientific method, which we understand today as an organized and efficient way of obtaining knowledge, is a recent acquisition, emerging from European thought during the last four centuries. This is almost nothing compared to the time our species has existed on this planet, endowed with the capacity to know and transmit knowledge, that is, to create culture.

THE SCIENTIFIC METHOD AS A COMPONENT OF THE GENERAL CULTURE

Culture is socially acquired, shared, and transmitted knowledge. The scientific method is an acquisition of culture and, as a form of knowledge, it can and should be within reach of a growing proportion of humanity, someday of all. This also was the case with the ability to read and write. At one time, it was exclusive to a small fraction of society and some societies. Today, driven by its functional value for the economy, literacy has been extended to many, in Cuba, to all. Could the same thing happen with the scientific method?

I am not referring here to the universalization of the benefits of the results of scientific research (which must also be guaranteed) but to the universalization—as a component of general culture—of the process of organizing the cognitive interaction with reality constituted by the scientific method. It's not the only way of thinking, but it is useful in many circumstances.

In José Martí's thought, we find this idea: "What makes the world grow is not to discover how it is made, but each one's effort to discover it. . . ."[3] Every person could interpret their reality by identifying the principal variables that determine the phenomena of interest (the health of a community, the productivity of a workshop, school performance in a classroom, the efficiency of a harvest), hypothesize about those variables, collect verifiable data, and compare data to the hypotheses' predictions.

This method does not work for everything. In fact, until now, science has explored only a small fraction of reality. But wherever it does work, everyone should be able to use it. There are also forms of knowledge and ideas that cannot be formally transmitted through oral or written language but through images, traditions, examples, attitudes, analogies, and practice. We have dealt with universalizing access to everything that can be transmitted and learned through reading and writing. We also have invested a lot of effort in promoting universal access to artistic culture.

Perhaps we should launch a new literacy campaign about the scientific method. Chimerical? In 1961, many used that term. "Literacy campaign" [*alfabetización*] offers an analogy that can be highly illustrative of the concept I am trying to convey. Today, most people understand literacy as the ability to read and write. But we should take it further and see it as the ability to use the most efficient means for capturing and transmitting knowledge. They are reading and writing, but we soon may not be limited to them.

The scientific method can be universalized much more than it has been thus far. Many people associate scientific research with laboratories full of complex equipment, but these are just the tools

through which we collect data from reality. True cultural innovation involves the intellectual process of identifying, organizing, and interpreting the necessary data. This process is quite independent of instrumentation. Scientific literature is full of examples of lax studies relying on complex equipment and jewels of methodological rigor and discoveries from simple observations.

Universal literacy greatly boosted the productivity of labor power. Who knows what productive forces could be unleashed as a consequence of the extension of the scientific method? The idea that science is now a component of the productive forces is almost commonplace. But what has been less evident so far (even though it is a direct consequence of that assertion) is that science must also be part of general knowledge, of the everyday intellectual practice of individuals.

The application of this concept poses enormous practical implications for those who direct scientific activity and education. First, we are confronted by a contradiction between the increasing specialization, sophistication, and cost of scientific research and the dissemination in societies of knowledge about and using the scientific method. How is this contradiction resolved? It is up to the current generation of scientists and leaders to find the creative core that, like all others, exhibits this contradiction and use it to motivate development.

SCIENCE AND CULTURE COME CLOSER TOGETHER

I have discussed science and culture as two forms of acquiring knowledge: analytic, systematic, reductionist, intuitive, synthetic, and holistic. On closer examination, we can see both as the poles of a continuum because of the increasing complexity of the phenomena and the number of variables involved.

The scientific method works whenever phenomena can be described in a few chief variables. Generally, predictive capacity is lost when variables increase and one resorts to intuition. It must be acknowledged that our thought cannot rationally manipulate

more than a small group of variables. We can, unconsciously or intuitively, but not systematically and consciously, grasp many simultaneous factors. The consequence is that when we try to approach intrinsically complex problems (the efficiency of economic systems, environmental change, the emergence of ethical values, the epidemiology of psychiatric disorders, the determinants of abstract thought capacity, immune system regulation, population dynamics, and I could add many more) through scientific methods, we tend to focus the analysis on three or four factors and ignore the rest, or to treat them as "noise variables." But the interaction of various variables with each other is most important. Complex systems lend themselves to creative intuition, holistic vision, and synthesis. They also are where the scientific method and its conclusions have been most frequently mistrusted.

This situation, however, is changing because of the revolution in computer science. System-focused methods that seek a total, nonfragmentary vision of complexity are being rapidly developed as a complement (and not necessarily in contraposition) to the Cartesian thought that privileges the analysis of components to the detriment of the context. Such methods increasingly allow the introduction of rational, systematic, exact, verifiable, and predictive thought in treating complex problems, until now only accessible to intuition. From these procedures arises the concept of "emergent properties" that characterize complex systems, some of which are not traceable to any single one of their components. A new notion of causality also emerges that differs from the mechanical causality with which we have operated so far, applicable to limited situations or ideal cases. Culture also accumulates knowledge about regularities that history demonstrates in the emergence, social penetration, prevalence, and changes in thinking.

At what point will they meet? No one knows, but science and culture are headed toward a convergence. It is probably more useful to treat them as aspects of a single phenomenon rather than separate phenomena. This idea has practical consequences, dependent on the increase in cognitive capacities of human communities.

THE CULTURAL DETERMINANTS OF SCIENTIFIC PRODUCTIVITY

Another widespread oversimplification regarding scientific research is that it is objective, not culture-bound, and supranational. But this is only a half-truth because science's objective character manifests in its results, which are universally applicable, not in the process by which those results are obtained, which is a social process with significant cultural influences. We can eliminate poliomyelitis in Africa with a vaccine invented in the United States and perfected in the USSR or vaccinate in China or Iran with the anti-meningitis vaccine obtained in Cuba. But the complex social process through which the search for knowledge is realized is far more difficult to transplant from one culture to another. Therein, perhaps, lies the failure of many imitative attempts to "sow science."

Science can be done everywhere, but it is done differently. Does this contradict the rational structuring of the scientific method? In fact, it complements it. The rigorous systematization of the scientific method (hypothesis, variables, measurements, statistical inference) refers to a particular form in which scientific questions are answered but not how the scientific questions are formulated. The latter draws upon intuition, creativity, and non-structural thought. No scientist can explore every possible road in their field; they must always choose a problem. Nor can they design all possible experiments to approach the chosen problem. One must choose, and there are no rules for this. Selection depends on what has been called "tacit knowledge," which is acquired through practice and cannot be explicitly expressed.

Ultimately, scientists are workers equipped for three tasks: measuring a phenomenon (and its components), evaluating and discovering associations between phenomena, and assessing the impact of human intervention on the real world. -Now, which phenomenon is more significant to describe among every possibility? Which components should be measured to discover something?

What associations deserve to be explored? What interventions have a higher possibility of being impactful?

Concerning the productivity of scientific work, the relevance (fertility) of this formulation of problems is what is most important. There is a method to find the right answers to questions, but not to find the significant ones. What is essential to discovery is to find the right question; its answer is generally accessible.

The cultural influence in this process becomes evident. Choosing a path is a matter of values that cannot be decided solely from logical, deductive reasoning. This creative, intuitive part of the scientist's intellectual process is intrinsically probabilistic. Conditions that increase the probability of the appearance of new ideas can be created, but it is not possible to predict, let alone program, their appearance. The original path, the imaginative question, the connection of distant pieces of knowledge, and the exploration of the non-obvious constitute the characteristic space of the small scientific collective: bold, innovative, creative.

Once an idea that may be good emerges, a second part of the process begins: the assessment and the method have been described, structured, and systematized for that. This is a deterministic process in which stages are articulated according to a discipline of methodological rigor by which the scientific community has been educated, and we can fairly closely predict when we will have the answers. Here something analogous to the "economies of scale" in production is at work, such as in the pharmaceutical industry, for instance, with many chemists obtaining molecules, many biologists assaying, automated procedures, and computer-assisted data analysis. This is the space of the big organizations of scientific research: the "factories" of discoveries. Here we know better how the system works, but the cognitive structure of the first stage of the process (the emergence of the "good idea") has been much less studied. That first stage is the part most articulated with the other components of the cultural space in which scientists work: the representation of reality, systems of ethical and aesthetic values, the imprint

of prior praxis (their own, that of their generation, that of their nationality). I will return to this point.

I must now mention another aspect of scientific work with undeniable cultural connections: motivation. Those who have studied researchers have looked for evidence of higher intelligence quotients than those from other professions. They have not found them. The particularities of committed scientists lie in the sphere of motivation. This motivation causes them to constantly, tenaciously, and obstinately put their intellectual resources under strain and mobilize them repeatedly, above every frustration. It takes a special perception of the world, one's place in it, the meaning of life, and the value of duty for an effort of this magnitude. And what is culture but the synthesis of all of this? This reflection may seem abstract, but it has enormous practical consequences: we will work on the motivation of those who bear talent and see the results. This is also José Martí's mandate. In one of his letters, he writes, ". . . the totality of man [*sic*] has to tend to unfold, and not just a side of him."[4]

Developing motivation; correct. But motivation about what? Must scientists be motivated by the necessity to know? Surely. Are they driven by the aspiration to contribute to the wealth of human knowledge? Certainly. Does this motivation suffice? We assert that it does not. Perhaps it did one hundred or two hundred years ago, but not now. Scientific research is a social task: human collectivities carry it out through certain individuals and not vice versa (as some describe it). It was always like this, although the social character of scientific work was perhaps less evident in the eighteenth century. Presently, however, the growing links among science and the economy, material well-being, education, culture, ethics, and health make evident in daily life the character of science not as an isolated work, valid in itself, but as part of a broader social work. We make science as a part of and a contribution to a societal project, of a vision of how things ought to be, as an expression of commitment toward a future that, we know, science, in and of itself, is incapable of building. Scientists know this, although perhaps many do not realize they know it.

No "curiosity for knowledge," no matter how necessary it may be, can be more motivating for the scientist than the conscious understanding of participation in materializing a human society project. The liberty of a scientist cannot have a more complete expression than the consciousness of this necessity. Let us reinforce this with actions.

José Martí highly valued science for constructing the society he envisioned and designed. "Science must be erected as the religion of the new age,"[5] he wrote. In a letter, he concisely expressed the synthesis of science and culture: "Where I find major poetry is in science books."[6] Martí's ideal of science is a sign for our people and a warning about the dangers he saw: not knowing how to assimilate universal science, not linking science to social practice, and turning science into a function of elites. Likewise, he perceived the error of reducing scientific creativity to the rigorous application of the "method" to the detriment of its culturally conditioned component of creative imagination. He told us: ". . . all science begins in the imagination, and there can be no sage without the art of imagining, which is that of guessing and composing . . ." and ". . . imagination is like a light that is ahead of reason, brightening it up so it sees what it investigates. . . ."[7]

THE SCIENCE-CULTURE-ECONOMY TRIANGLE

Having noted the links between science and culture, let us now complete the triangle with the links of both with the economy in the sense of the enlarged reproduction of material life. It has been said repeatedly that we are entering the era of the knowledge economy. This expression seeks to capture a set of trends, such as the reduction of obsolescence in the products that are traded and, therefore, the growing need to renew them, that is, to innovate; increasing the knowledge component (the value of technology, the know-how, labor-power qualification) in the products' price relative to the material components' costs (note the weight of the "knowledge" component in the production cost of a new medicine

or computer); increased commerce in intangible goods (patents, technologies, trademark rights, consulting firms, projects), and the reinforcement of intellectual property systems.

As we will see, some of these processes are related to a deeper one, a change in how capitalism appropriates the results of socially performed work. These processes are present in all productive and service sectors, although they are more evident among certain so-called high technology sectors characterized by high costs of skilled labor and the ongoing research process they demand: the manufacturing of computers; automatized production systems; telecommunications; high technology polymers and plastics; new materials; the pharmaceutical, aero-spatial, software, and microelectronic industries, among others. In these sectors, the industrialized nations thrive as they export the technologies of the previous wave to other nations.

What is really happening in those high technology sectors is a shift in the center of gravity of competitiveness, formerly located in the technological capacity to apply available knowledge, which now situates itself increasingly in the capacity to generate new knowledge. This is a matter of relative speed: when the speed of the practical application of knowledge was low, it was the determining factor of the whole process. But in an age when knowledge is applied to production almost instantly, the determining factor and the competitive advantage lie in the generation of knowledge.

Economic transactions have always been, ultimately, cultural transactions. The buyer's resources (purchasing power) are exchanged for the capacity to solve a seller's problem. The commodity is the material element that mediates this transaction. What is ultimately happening is that, with the transformation of knowledge into a product so expeditious, the object of the economic transaction is knowledge itself. And as we start to see the economic transaction in this way, a new vision of the enterprise surges as the sum of articulated knowledge to a specific end. This may seem exaggerated, exclusive to particular cases, futuristic ahead of time, and whatnot, but that is the tendency.

In his book on the new economy, *The Third Wave*, Alvin Toffler concluded, ". . . for Third Wave civilization, the most basic raw material of all . . . is information; including imagination."[8] Thus, the long-term viability of economic systems (at the enterprise, national, or regional groups of nations levels) is related to the knowledge-generating capacity that they can install and maintain.

How does scientific research capacity influence the economic viability of nations? How does culture influence the motivation and creative capacity of scientific and technological systems and production? What economic mechanisms can efficiently support the development of science and culture? How can science, culture, and economy mutually reinforce each other? Once again, there are more questions than answers. We have already seen that what is essential is to identify the right questions. These lie in the center of the triangle formed by science, culture, and the economy.

TOWARD A NEW THEORY OF COMPETITIVE ADVANTAGES

Several years ago, a book was published that greatly influenced economic thought.[9] It espoused a theory in which the interaction of different factors progressively constituted an area of competitive advantage in production in certain sectors for each nation. This is the case for chemical products in Germany, pharmaceutical and service-financial products in Switzerland, heavy trucks and mining equipment in Sweden, computers and software in North America, packing machinery in Italy, and consumer electronics in Japan. Every nation should find its zone of competitive advantage and maximize its exploitation without seeking to compete in all sectors.

Michael Porter's analysis focused on the competitive advantage in relation to the production of goods and services. Now, if the predictions of the previous section are correct, what will happen when the main determinant of economic efficiency is the capacity to generate knowledge? Do competitive advantages for the generation of knowledge exist? This is the central question. The view of

science as a rational, objective, extra-cultural, and supranational phenomenon of linear accumulation of knowledge would answer the question negatively and conclude that science is done the same everywhere, depending on the investment in human and material resources. I do not share this vision, not only because I consider it mistaken but also because it offers few opportunities for small countries struggling for development.

An alternative vision of science as a component of the complex process of grasping and representing reality, integrated with many other components of culture, suggests that, indeed, we can find areas of competitive advantage in producing knowledge, even for the less developed nations.

The conclusion from this reasoning is that if competitive advantages exist, they are to be found in nations' cultures. Such advantages will depend on the system of ideas, images, values, and social influences that culture builds for each individual and for each collectivity that practices science or creatively uses its results. The cultural system should provide a framework that supports motivation, boldness, and tenacity; offers points of reference in the national cultural and scientific tradition; recognizes tacit knowledge and analogous situations on which to base creativity; considers alternative approaches to the same problems investigated by other scientific groups; and communicates with other sectors of social activity to extract problems and ideas and effectively apply results.

It is not a matter of identifying all the cultural determinants of scientific productivity or even those that may be more fertile in the Cuban sociocultural context. This must be a task for many and may take a long time. For now, it is a matter of stressing that the determining factors of scientific productivity must be sought outside the sector that we have traditionally called "science and technique" and that they depend on the cultural and ideological context in which science operates.

Theory is made so that practical uses can be extracted from it. This means that we have to reinforce, with strategic design and

actions, the rich influences that cultural heritage (including the political-ideological) historically accumulated in Cuba can exert on the scientific sector. The process goes in both directions: the practice of scientific research is already part of social practice in our country. Scientific research must also contribute to Cuban culture, and those who conduct what is central to cultural work have the important task of capturing, reflecting, expressing, and integrating this emerging part of our reality into Cuban spiritual and artistic culture. This will undoubtedly be an enriching exchange.

NATIONALITY AND UNIVERSALITY IN SCIENTIFIC WORK

Science and sovereignty influence each other. In future decades, the autonomous capacity for the creation and social application of new knowledge will increasingly be an indispensable requirement for the economic (ultimately political) viability of nations.[10] Until the planet becomes communized, the exploitation versus sovereignty contradiction will continue to exist, and battles will be fought in the most decisive fields to reproduce material life. Once, it was access to trade routes, then to sources of raw materials, then the ownership of industrial facilities, and more recently, the protection of markets and access to technology. The generation and control of knowledge will be the new battle with capitalism. For scientific development to serve the cause of national sovereignty, it will be necessary to fight, expropriate, and redistribute.

Now, let's examine the problem from the opposite direction: the need for a solid national identity and culture (and scientists' identification with it) so that scientific work can be productive. We have always recognized the need for a national culture, a national literature, and a national character of education. In science, things have been less clear, and there has been no lack of those who have fallen into the trap of universality, misinterpreted as a loss of roots. As we study the links between science and culture, it will become evident that a universal contribution can only begin from national roots in the former.

Scientific creation is a task for human groups, not just individuals, and the integration, communication, and functionality of these groups is key to efficiency. Scientists' intuitions are not really individual (although individuals always express them) but the product of a complex interaction among groups, the richness of which cannot be reduced to the exchange of pieces of verifiable information. Situating scientific work within national culture and in integration with it is crucial not only for the defense of national sovereignty but also because it is the best way to contribute to universal scientific knowledge.

The geographical concentration of science in a few countries (currently, the countries that make up 75 percent of humanity have less than 25 percent of scientists) and the standardization of its procedures and value judgments do not benefit anyone, not even the most developed countries. Ultimately, it will end up impoverishing creativity. This is because knowledge advances not only through completely new discoveries but also through the recombination of knowledge and different approaches to the same problems.

In his classic work on the philosophy of the sciences, Thomas Kuhn explained how so-called normal science operates in the context of a set of ideas shared by a scientific community (the paradigms) and how the accumulation of anomalies, not foreseen by the paradigms, progressively conditions their replacement.[11] The sensitivity of scientific communities to possible problems, the value system that gives them importance, the capacity to perceive and react to anomalies, and choosing among competing paradigms are complex cultural phenomena that are not susceptible to analysis using the criteria of normal science. We should seek diversity in our approaches, not standardization.

THE COLLISION OF CAPITALISM WITH THE FUTURE

Is capitalism compatible with a knowledge-based economy? Most of the world is ruled by a system characterized by private

ownership of the means of production. The means of production become capital, and capital accumulates and expands with the private appropriation of the surplus value generated by socially performed labor. This is how the system works.

What will happen when the fundamental factor of production is knowledge and the capacity to create knowledge? Is this appropriable? To meet this challenge, the ideologues of capitalism have invented the concept of intellectual property (patents, trademarks, industrial secrets) and have imposed on the world their universal recognition in the TRIPs (Trade Related Intellectual Property) agreements, a product of the last "Uruguay Round" of the GATT agreement; and the World Trade Organization watches over their application. It is like imposing the recognition of private property on knowledge, a product whose social origin is clearly evident. We are already witnessing multiple conflicts in biotechnology, computing, biodiversity resources, and many other areas because the system simply does not work.

The logic of the patent system is that of return on investment, an attempt to apply the laws of the market to the products of scientific research. But no one can own everything necessary to manufacture knowledge: it is a product of culture. And, as the links between scientific productivity and cultural heritage become more evident, to whom should the investment in creating culture return?

The productive system of the knowledge economy will have many economic externalities, social factors that determine productivity that an enterprise uses without paying for them. In fact, what we consider today to be complementary externalities (available knowledge, people's education, motivation, and social environment) are the main factors of competitiveness. The conflicts we see in applying the patent system to high-technology sectors indicate that what is wrong is not the patent system itself but the broader system of ownership of the means of production and the appropriation of the products of labor that gave rise to it.

As productivity depends more on non-appropriable social components such as knowledge and culture, the contradiction

between the social character of production and the private character of appropriation will become more evident and acute. We are already seeing it in the intellectual property conflicts that proliferate in biotechnology (it is the area that I know best, but there are examples from other fields) that, in many cases, have the effect of postponing the practical application of research findings, limiting access to products, discouraging research projects that might have a property conflict, increasing investment costs in scientific capacity building, skyrocketing spending on non-productive and other services.

The knowledge privatization system is not only unjust and immoral but also dysfunctional. It will end up as a system of relations that will slow the development of productive forces. (Let us return to Karl Marx.[12]) Capitalism will collide with the future. We need to discuss what we must do to accelerate the collision.

What is to be done?

I use the title of Lenin's famous work, *What Is to Be Done?* to remind us that analyses are not monuments to be contemplated but tools to be used.[13] In practical terms, where do these reflections on the links between science, culture, and economy lead us? We have to continue to delve into this topic to identify and enhance the elements of Cuban culture that may have the greatest impact on scientific creativity, innovation capacity, the recombination of knowledge between different areas, the circulation and penetration of knowledge within society, and its transformation into applications. Then, we must make explicit all findings from this inquiry.

We must continue to form scientific cadres. Competitive advantage lies in people, their quality and their quantity. With published data from different nations, an almost exact correlation can be constructed between the number of scientists per inhabitant and the Gross Domestic Product (GDP). Cuba is an exception, having a GDP per capita similar to that of Latin America but with numbers of scientists and engineers comparable to that of Europe and four times higher than that of countries with a similar GDP. This

deviation cannot be rectified but amplified, as long as it is economically sustainable. Market-driven societies cannot sustain this decoupling between current GDP and investment in human resources for the future; the Cuban socialist society can.

We must prepare for international economic negotiations increasingly based on intangible assets (ongoing projects, patents, cadres, social context, technologies, past labor). The establishment of costs and prices of these assets is very complex, and so are the negotiations about them. We have to train more specialists in the economic and legal aspects of this type of negotiation.

We must continue to study the specificities of the Cuban scientific-technical developmental experience. Cuba has incorporated elements from many models: France's National Center for Scientific Research, the USSR Academy of Sciences, U.S. biotechnology companies, and others. This is not a bad thing ("graft the world into our republics," said Martí), but each of these models of organization and development has roots in the cultures that originated them. We are seeking a synthesis within the Cuban cultural crucible. Of course, life itself is generating it, but we need to analyze, structure, and explain it.

We have to stimulate the circulation of knowledge in society and the recombination between different fields of scientific and cultural creation. Knowledge's impact depends on its volume and the intensity of its circulation. We must intensify our scientists' ideological and cultural education, preparing them so that they not only know what they do but also why and for what purpose and understand their work's relationship with others. Such scientists would be those who make the inheritance of ideas and values delivered by our history theirs, who understand their world to better help the whole world.

I have not sought to write something conceptual, with an agenda with a due date and persons with assigned responsibilities. I have tried to point out how preoccupations might be transformed into occupations. This is all very complex and difficult. Capitalism's internal dynamics have forced humanity into an absurd race of

wealth concentration and marginalized many. No one knows where this will lead us or if there will be sufficient consciousness and moral commitment to reverse the process. But we must face this daunting reality with courage and ideas, even if it may seem impossible. At a session of the Cuban Parliament in July 1998, I wrote down this comment by Fidel Castro, with which I want to conclude: "A revolution is a fight against the impossible, and the possible is achieved by always fighting against the impossible."

CHAPTER 4

The Knowledge Economy and Socialism: Reflections from the Cuban Biotechnology Experience

This chapter summarizes general and provisional conclusions drawn from more than twenty years of building a new sector of the Cuban economy: biotechnology. But this analysis is not limited to biotechnology. It is essentially concerned with scientific research as a part, and primary component, of the value creation chain for the economy.[1]

The emergence of what is called the knowledge economy has been the object of many theoretical studies and also of several studies of concrete experiences. The experience of Cuban biotechnology, as we shall see, is not like others. Its particularities point to aspects of the problem that have not been previously analyzed and extracting new conclusions. The main conclusion is that in a knowledge-based economy the failure of market mechanisms and the contradiction in capitalism between the social character of production and the private character of appropriation—a contradiction that only socialism can overcome—become ever more evident.

ANTECEDENTS: THE FORMATION OF HUMAN CAPITAL

When in January 1960, Fidel Castro said that the future of our homeland must necessarily be a future of science and thought, Cuba had more than one million illiterates in a country of 5.8 million inhabitants and an elementary and middle school educational attainment of 55 percent and 16 percent. During the 1961 literacy campaign, more than 270,000 voluntary teachers participated, and seven hundred thousand people were taught how to read and write. This epic battle was furthered by the massive training of teachers, the creation of a totally free education system, the construction of elementary and middle schools and pre-university institutes in every province, and the expansion of higher education.

Between 1959 and 2002, the number of schools went from 7,679 to 12,717; teaching personnel increased tenfold, from 22,800 to 258,000 (289,279 at present), and the total matriculation at every educational level went from 811,300 to 2,430,000 (3,081,117 at present). Elementary school educational attainment is currently more than 98 percent, and high school more than 84 percent. The number of higher education centers increased from three to fifty-four (sixty-five at present), with college instruction in every province in the country and an ongoing process of expansion toward all municipalities, with more than three thousand university venues. More than forty thousand annually graduate from the higher education centers. Between 1959 and 2008, Cuban universities produced 918,926 higher education graduates. Today there are more than a million.

In tandem with the educational network, starting from practically nonexistent bases dating from the pre-revolutionary era, a web of scientific research institutions began to emerge and expand until it reached its current composition of 221 research centers, where more than thirty-one thousand people work. In 1965 (while Cuba was still battling counterrevolutionary groups), the National Center of Scientific Research [Centro Nacional de Investigaciones Científicas] was inaugurated and, in 1966, the Research Institutes

of the Public Health Ministry [Institutos de Investigación del Ministerio de Salud Pública]. In 2000, the number of full-time scientific researchers was estimated at 5,738, at a ratio of 1.15 for every thousand economically active people. If university professors are also included, this indicator reaches 3.0, a much higher figure than Latin America's mean and equivalent to that of Spain, Holland, or Austria. The number of Cubans working in science and technology today is estimated at more than seventy-one thousand, of which more than forty-six thousand are at the college level.[2] From the 1970s, thousands of young scientists finished their training abroad. By 2007, 9,712 scientific degree certificates had been issued.[3] Cuba currently has the world's highest physician and teachers per inhabitant. According to the UNDP, Cuba qualifies among the High Human Development countries, occupying fifty-ninth place among 187 countries.[4]

This educational process has two profound political roots. The first is the abandonment of the naïve ideas of some development theories that education, health, science, and culture will result from economic development. The practical strategy of the Cuban Revolution was exactly the opposite: education, health, science, and culture are, in today's world, preconditions for economic development. All of them must be accessed directly and rapidly. Besides, access to education, health, and culture must be massive and equitable. All this must be built through political will and not left to supposedly spontaneous mechanisms. Social justice is achieved through politics, not through the economy. Economic development will come later based on politics.

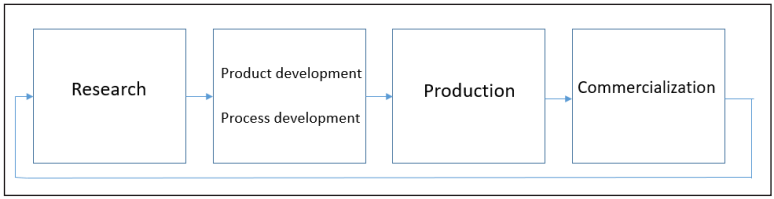
The other political root that nurtures educational development lies in the origin of economic surpluses that make investment in human capital possible. These resources exist even in underdeveloped economies but are appropriated by the national (and anti-national) bourgeoisie and largely transferred to the rich countries' economies. The revolutionary interruption of this vicious circle of underdevelopment placed the resources for massive development of education in Cuban hands. Our human capital

has served as a launching pad for the scientific research of the last twenty years.

THE KNOWLEDGE ECONOMY

From the 1980s on, knowledge began to be the main economic asset of developed nations. This stage has been called a Third Industrial Revolution, the first being the rise of industry in Europe in the eighteenth century, the second occurring with the twentieth-century rise of an economy based on oil, electricity, and generalized mass industrial production. There is widespread consensus that the current and third stage is that of a scientific-technological revolution. However, consensus is weaker when one tries to specify the exact meaning of the knowledge economy. Some identify it with the emergence and widespread use of computers; others, more broadly, with microelectronics and telecommunications, with others adding among its main features the emergence of new concepts about the generation and use of energy, and of new materials. An overlapping perspective identifies the process with expanding the service sector and information management, including the entertainment industry and the "production of affection."

It is difficult to distinguish the external symptoms of the underlying essential processes, especially when not enough historical time has elapsed to see them in perspective. But, even so, what is undeniable is that we are witnessing the emergence of economic sectors that generate products with a high knowledge content both in value and price (partly because of the high qualifications of the workers who produce them), where knowledge is the limiting input and the chief determinant of competitiveness. Productive sectors are generating innovative products with short life cycles, with an increasing portion of a company's income frequently obtained from products that did not exist five years ago, and where there is more competition over product differentiation than over the high scale of production and low costs. Or in productive sectors whose



companies implement scientific research using highly-qualified labor and systematically negotiate transactions about intangible assets (technologies, patents, brands). Or in productive sectors where the exclusive, or at least advantageous, appropriation of knowledge allows the imposition of monopoly prices on products, which are far above production costs.

These features can be found in diverse sectors: microelectronics; telecommunications; the software, aerospace, and pharmaceutical industries; fine chemistry; biotechnology; and new materials, among others. Some include specialized or nature tourism as a sector based on knowledge. These sectors are not yet the most influential in the economy, but their participation increases as they grow.

What underlies this apparently diverse symptomatology? Basically two phenomena: the first is integrating scientific research as part of the value chain of productive processes.

Research ceases to be an economic externality from which companies benefit without paying or buying in the best-case scenario, as in traditional economies. Now, scientific research increasingly forms part of the daily activity of companies and is internalized into their costs.

The second phenomenon is the need for higher workers' qualifications and greater motivation and creativity so that they become productive in the knowledge economy. Workforce enhancement creates more and greater connections among productivity, education, and culture.

A third, quantitative one is derived from these two phenomena: the production of value-added products, in which value and price

are far above the cost of the material components constituting them. The value of knowledge accounts for this difference.

We begin to notice the limitation of the conceptions that identify the knowledge economy with the service sector or certain high-tech sectors. These conceptions show the main thing. The processes I have described are more evident in extreme high-tech cases. But the increasing role of science, knowledge management, education, motivation, culture, and creativity will penetrate, and become evident to a greater or lesser extent, in all sectors of material production, from cybernetics to agriculture, broadening the knowledge content of all production and services.

THE EMERGENCE OF THE CUBAN BIOTECHNOLOGY SECTOR

A comprehensive analysis of the experience of Cuban biotechnology has not yet been written by any of its protagonists (although there have been attempts by external observers that exhibit the usual biases and limitations). This work is not such an analysis either. I will limit myself here to explain why this experience does not resemble others. Its unique character allows it to be a starting point for interpreting the fundamental processes underlying the transition to a knowledge-based economy.

Biotechnology is essentially the use of bacteria, yeast, and vegetal and animal cells, whose metabolism and biosynthesis capacity are oriented to producing specific substances. Biotechnology is, above all, a production process.[5] The technological premises for expanding this type of productive process were laid in the 1970s after cloning and gene expression (genetic engineering) technologies emerged and the development of large-scale cellular culture techniques, fermentation, and chromatographic purification of biomolecules. The transformation of these technologies in industry was initiated in the United States during the late-1970s and early-1980s with the emergence of multiple small biotechnology companies that took advantage of that country's favorable economic moment to mobilize private investors or stock exchange

venture capital. In Europe, an equivalent process did not begin until the late 1980s and access to venture capital did not occur until the mid-1990s. It is estimated that there are a little more than four thousand biotechnology companies worldwide, of which almost half are located in the United States, the remainder in Europe, mainly in England and Germany. In the rest of the world, this phenomenon is still incipient.

In Cuba, under Fidel Castro's guidance, the Biological Front was created in 1981, initiating the establishment of research-production centers spanning the 1980s and the first half of 1990. This process led to the creation of the Scientific Pole of western Havana, a complex of more than forty institutions that employ more than twelve thousand workers and more than seven thousand scientists and engineers. To a lesser extent, biotechnology also extended its activities to other provinces, mainly Camagüey, Sancti Spíritus, Villa Clara, and Santiago de Cuba.[6] With the hindsight of more than forty years, one can see how precocious was our incorporation of an industry that was just emerging in a few highly industrialized countries. The combination of Fidel Castro's strategic vision and the immense work of human capital development by the Revolution made this possible.

The experience of Cuban biotechnology has been successful by whatever indicator is used to measure it: product generation (medicines and vaccines), impact on public health, patents, exports, cash flows, cost by weight, return on investment, or others. The sector continues to expand, and, in fact, even higher economic performance is expected. There is not enough space here to enumerate the products and their impact. But the following are some highlights:

- More than twenty medicines and vaccines have been incorporated into the health system.
- More than 1,700 patents have been registered abroad by Cuban institutions, covering more than 190 inventions.
- Novel vaccines for meningitis B and Haemophilus have been

developed with our own technology. Cuba's Finlay Vaccine Institute developed two COVID-19 vaccines, Soberana 1 and 2. In 2021, Cuba's Center for Genetic Engineering and Biotechnology developed a third Covid-19 vaccine, Abdala, which has proved "highly effective in preventing severe illness and death from COVID-19 under real-life conditions."[7] This also developed the first Covid-19 vaccine for nasal administration, Mambisa.[8]

- Cuba has the highest vaccine intensity and coverage (fourteen) worldwide.
- The incidence of meningitis and hepatitis B and A has been reduced, reaching zero in the population under fifteen.
- Ample access exists for the whole population to high-technology medicines (interferons, erythropoietin, monoclonal antibodies, and others).
- A national network of more than two hundred high-tech immunodiagnosis laboratories conducts active research with full coverage for several diseases.
- New drugs for cholesterol reduction and for heart attack treatment have been developed.
- A national network of neurodiagnostics with high-tech equipment.
- Direct links to health programs for infant mortality, cancer, and diabetes, and nutrition programs.

Note that this list includes data on products and technologies and their impact in modifying health indicators at the population scale. Here we see not only a health phenomenon but also an indication of science operating in a social context.

Over more than twenty-five years, Cuban biotechnology has become one of the national economy's main export sectors. Cuban biotechnology products are registered in sixty-six countries, and exported to more than fifty countries. They generate a positive cash flow that supports the system's expansion. As value added per worker, labor productivity in the biotechnology sector triples the national mean.

These remarkable results are particular to the Cuban experience since most biotechnology companies that emerged in the United States in the early 1980s have not become profitable, with many engulfed by others (especially big pharmaceutical companies). It is estimated that only 20 percent of U.S. and European biotechnology companies can finance themselves through their product sales. They operate through venture capital injections or funding obtained by shares sold on the stock market, which allows them to continue investing at the expense of possible future earnings.[9]

Compared to other biotechnology investment experiences and technological parks, the Cuban experience demonstrates features that make it unique. It occurs in an industrially underdeveloped country with scarce resources and that is also subjected to the longest and most intense economic blockade by and the hostility of the greatest economic power known to history. It occurred simultaneously with the disappearance of the European socialist bloc, which precipitated our country into the economic crisis (a loss of 35 percent of the GDP, 85 percent of exports, and more than 75 percent of the fuel supply) we know as the Special Period.

A technocrat analyzing the incipient efforts of Cuban biotechnology in the late 1980s could have concluded that all the conditions for failure existed. Cuba lacked a base for industrial development. It had no supply chains for high-tech products, no internal market with sufficient volume, no history of being a medicine exporter, and no established commercial channels. Additionally, it had to contend with the U.S. blockade. In fact, U.S. government documents state that Cuban biotechnology should not exist. Today, that technocrat would admit he was wrong but would not understand why.

Amid this difficult context, Cuban biotechnology continued to grow and began to export. The fundamental reasons connect economic productivity with the formation of values, as well as with justice and massive access to knowledge. Cuban biotechnology arose as an investment of the socialist state, without resorting to foreign investment (unavailable anyway), and the defense of

social property over its tangible assets. It emerges and develops against all the recipes and probabilities that biotechnology analysts in other countries could have established. This experience radically differs from that of many so-called technological parks that have been created (and studied) in many countries and which, in underdeveloped countries, have generally been guided by foreign private investment by multinational companies. They also are characterized by the transfer of incomplete production processes (which often have a proletarianizing effect on local workforces while generating little local technological development. In hindsight, this was to be expected; capitalism never transfers the main limiting resource of competitiveness, which in high-tech sectors is the capacity to generate new knowledge.

THE UNDERLYING PROCESSES

I now will identify the common features of the different biotechnology centers and projects to glimpse two very important things: the fundamental reasons for their successes and their relation to the socialist character of the society in which they have occurred. The following three features are essential to the Cuban biotechnology experience.

1. *The research-production center or the whole-cycle institution.* The main biotechnology centers in Cuba were built for research, production, and commercialization. This meant the cycle—research, obtaining new products, assembling the productive process, production, and distribution in Cuba and abroad—was completed under the same administration. Thus the often artificial barriers between the scientific institution and the factory, and between the latter and commercialization, disappeared. A rich, informative flow was created, which made the decisions about scientific projects appear productively and commercially viable, all while valorizing the intangible component (knowledge value) for commercial negotiations. A shared sense of responsibility for the success of the whole process was created, and not just for a part (as

commonly occurs in organizations fragmented by specialization or private property).

Coexistence and cross-pollination between the ways of thinking (cultures) of the lab researcher, the producing engineer, the specialist in regulations, and the commercial specialist were created. This coexistence generates several contradictions, which are essentially creative.

Scientific centers were built equipped with productive capacity, and this is a very important characteristic. In fact, most biotechnology companies in North America and Europe today do not have any productive capacity and seek to obtain it through manufacturing contracts, which has progressively created a formidable bottleneck of limited productive capacity for most biotechnological products being assessed in clinical trials. Today, in the principal centers of Havana's Scientific Pole, the production process occupies more than 60 percent of personnel and current expenditure.

2. *Export orientation.* In small countries (including industrialized ones), domestic markets lack the size to generate an operation of enough volume to internalize fixed costs on research and development and quality assurance systems. Therefore, an export orientation was seen as a precondition for economic viability. Cuban biotechnology products are currently exported to more than fifty countries on all continents. The resources for operating and growing this system are derived from these exports. But, less obvious although very important, exporting is also a source of information about the value of our products and their competitiveness, as well as about new needed products and their required properties. Without this information, it would not be possible to work properly, and it is not obtained anywhere but through daily contact with the places where the products are used.

The Scientific Pole's exporting activity finances this component in the currencies of the products destined for the Cuban health system, and this enables Cuba to not give a market character to the relations between biotechnology centers and the health system.

This reflects a very important ideological concept: Cuban people are not customers. Quite the opposite: the Cuban people are the socialist owners of institutions and are served as such.

Certainly, there is an inherent complexity in maintaining market relations abroad and socialist distribution relations within; but it is precisely a complexity that we need to learn how to manage, for it contains the seed of a superior form of communist distribution of the results of social investment in science and technology. We need to make this seed germinate, and, someday, to the extent to which fair terms of exchange are obtained, it will progressively spread to relations with other Third World countries. Cooperation in health (which includes supplying medicines and some biotechnological products) with the Bolivarian Republic of Venezuela begins to anticipate the future we aspire to. At the global level, we are still far from the establishment of socialist exchange relations among countries, but reality, and the human rationality which we must trust, will progressively impose South-South cooperation forms, which will gradually clear the road. The knowledge economy constitutes a favorable space for this.

3. *Treating scientific research as investment.* As scientific research became more directly connected to productive processes, it started losing its character of budgeted expense and acquiring one of investment, to which it is possible to associate one (or several) financial scenarios, a net present value, and a return rate. This is not about imposing a deterministic approach on the research-development process, even less so a rigid plan. Research and development projects treated as investments distinguish themselves from other investment projects (real estate, oil, tourism, or others) precisely by their high-risk component. We have to expect uncertainty. But even so, the economic analysis of projects, including the study of the project's sensitivity to the main economic variables, generates knowledge on the limits of its viability, which is notably superior to that available when this exercise is dispensed with. Researchers have gradually understood that there are limits to their intuition for appreciation of the economic feasibility of a project, limits

given by the number of variables at play and that a sort of assisted intuition by analysis instruments is needed.

Given the uncertainty inherent in the probability that research on a novel product is successful (research is, by definition, the realm of the *a priori* unknown result), decision-making cannot be mechanically linked to the results of a probable cash flow and return rate analysis. But the realization of these analyses constitutes an intellectual discipline that creates the habit of permanently looking at the whole cycle of research-product-process-market and the differentiation strategy in relation to competition and ends up contributing to the final objective of tightening the connections between science and the economy. The implementation of this analysis discipline has required, among other things, the training of many scientific leaders in techniques of Integrated Project Direction.

WHAT IS ECONOMICALLY RELEVANT KNOWLEDGE?

The concept of knowledge economy is broader than the relations between economics and scientific research. Of course, it includes such relations, but it is not reducible to them. Scientific research generates structured knowledge that is transmissible, specialized, and generalizable. However, there is also economically relevant knowledge characterized by other properties:

- It is collective: it is not incorporated into any other person or specific document but embedded within the productive organization's system of relations and work procedures. It is in the culture of the company.
- It is combinatory: it is produced from pieces of information from very different specializations and fields of knowledge.
- It is concrete: hard to generalize and linked to both productive and specific service applications.
- It is tacit: hard to formalize into rules and sometimes hard to explain.

- It is local: it is generated and used in each productive organization.

These two forms of knowledge (structured and tacit) are extreme cases. Real-life economically relevant knowledge combines structured and generalizable knowledge (scientific in the conventional sense) and tacit and concrete knowledge. The main idea here is that efficient management of knowledge, directed toward enhancing its role in the economy, must consider both extreme forms and their combinations. To manage knowledge for the productive organization of the new economy means to identify it when it is generated, to grasp or fix it into patents or products and processes' norms, to assess it, circulate it, and transmit it in an organized fashion via training. All of these are concrete tasks.

In our context, the concept of research-production centers tightened the links between scientific research and the economy and also in many activities of a broader scope focused on circulating concrete knowledge, such as the Science and Technique Forum, the National Association of Innovators and Rationalizers (ANIR), the Youth Technical Brigades (BTJ). It becomes evident that, as knowledge plays a more important role in the economy, not only does the quantity of it that is generated and used increase, but the mechanisms by which this occurs also change.

In the past model, which I describe as "introduction to investigation results," the creation and use of knowledge were separated in time and space. Knowledge was generated at a given time, within an academic institution or scientific center and was then applied, in another moment and institution, in this case, of production or services. This model has not disappeared, but now another one emerges with ever more strength, wherein the generation and use of knowledge occur simultaneously and within the same organization. Again, research-production centers are an expression of this phenomenon, as are the increasing numbers of industries that incorporate research-development unities into their structure.

KNOWLEDGE ECONOMY AND COOPERATION

From the outset, the Cuban biotechnology system was precisely that: a system. It prioritizes cooperation (and integration) among its institutions not competition. This integrative concept extends beyond the limits of the biotechnology sector and encompasses connections with public health, agriculture, and higher education institutions, among others, in an extensive and growing network of cooperative interactions. The construction of cooperation networks is thus a concrete form of system growth, which will be more accelerated than the organic growth of the system's institutions.

Our socialist ideology always has rejected market relations and competition in the search for profit, as they generate inequalities and social injustice. We continue to reject them on that basis, but we have also learned that, as we transition to a knowledge economy, market relations are not only a source of injustice but also a source of inefficiency. In the knowledge economy, cooperation is more efficient than competition.

The speed at which new knowledge is generated in the high-technology sectors is greater than at which the consequences of each new piece of knowledge (or each technology) can be explored in fields or institutions different from those where they emerged. This creates potential creativity in knowledge recombination and technologies coming from diverse, even distant, fields and institutions. To pretend this process will occur through market relations on "owned" knowledge would generate ever more transition costs and insurmountable contradictions. The elevation of barriers to the circulation of knowledge (as patents, industrial secrets, or others) sacrifices efficiency for the sake of private property and will end up turning into a barrier to technological progress itself, imposed by capitalist production relations that will not adjust to the level of development of the new productive forces anymore. Under socialism's conditions, high circulation intensity and knowledge recombination are possible. Organizing and stimulating it are concrete tasks for those in charge of scientific-technical activities.

NEGOTIATING INTANGIBLE ASSETS

At the end of the value chain, there is always a negotiation whereby knowledge arising from the investment of certain resources turns in enlarged form into new resources. Part of these resources contributes to the enlarged reproduction of the economy, and another part is reinvested in scientific research, thus creating an enlarged reproduction sub-cycle of knowledge itself.

How is knowledge transformed into value? This topic still requires a lot of study. There is a first, more obvious answer, and it is that this occurs through the incorporation of knowledge to tangible high-tech products (a new medicine or a new vaccine, or new medical equipment, for example) in whose price the value of knowledge gets internalized. Another less obvious but feasible way is negotiation about knowledge itself, which can occur in elementary form through patent licenses or in a more advanced form through contracts with foreign firms for the joint development of a new product via high-risk investment. In these contracts, the foreign partner contributes venture capital for the continuation of the project and realizes pre-commercial payments whose amount valorizes the past knowledge created by the Cuban part and receives in exchange commercial rights in given territories that will be effective if the project finally generates a marketable product.

The Cuban part cedes a fraction of the added value it could obtain if it commercialized the product, but in exchange, it wins development time (which accelerates the entry of money) and time to penetrate the market (if the counterpart possesses channels for it). These times can be determinants of profitability.

The experience of Cuban biotechnology for product development has been to implement a combination of a strategy of whole product development (to negotiate just commercial representation) with precocious (pre-commercial) negotiation strategies. Social property over the means of production is a principle of socialism. The principle, also supported by the socialist charac-

ter of property, has been to never negotiate about the facilities' tangible property or hiring qualified labor power. The object of commercial negotiation is the products, either completed or in progress, but never the productive forces that generate them.

Negotiations on intangible assets are complex, and in biotechnology, not enough time has elapsed, nor has there been sufficient experience to build objective criteria for estimating the value of a project (not the cost, but the value) or its risk. To a great extent, part of the estimations is intuitive and based on perceptions that, when shared by several potential partners, acquire an objective character. In this field, we have had to fight an image war against the United States propagandistic media machine and the dissuasion effect of its extraterritorial laws. But we have been learning and progressing; the fact that the Cuban biotechnology system has been able to operate for years with a positive cash flow in national and foreign currency, recuperate the original investment and create surpluses to reinvest demonstrates that there has been accelerated and timely learning, although there is still a long way to go.

We have to foresee that as knowledge in sectors of the economy is transformed into a component of the value chain, there will be ever more commercial transactions about knowledge itself, and we will have to build a theory of value that is adequate for this new situation. This will create increasing contradictions, again a consequence of capitalism's attempt to treat a common good (knowledge) as private property and a commodity. But, in the real world, we will still need to coexist for a while with these contradictions.

Experience from dozens of negotiations between Cuban biotechnology institutions and foreign entities shows how difficult it is to create points of reference that are acceptable for both parties, given, among other things, the fact that, when there are negotiations over a new product, and even more over the possibility of a new product, the future market realization is not known. This initial negotiation experience also warns us of the possibility (as with

commodities) of unequal knowledge exchange between rich and poor countries, whereby the establishment of value criteria ends up in the hands of the rich. The North-South transfer takes the form of costly, highly value-added products. In contrast, that from South to North takes the form of selective emigration of qualified labor power paid at its reproduction cost and not for the value it creates. That is, a clear situation of capitalist appropriation of surplus value, now expressed in the field of the knowledge economy.

Negotiating over intangibles, which requires a proper valorization of created knowledge, will be inevitable. Unlike natural resources (oil, for example), knowledge is a perishable asset that holds a high value when precocious and then loses it in time and in an accelerated fashion. The risk of negotiating will always have to be compared with the (not negligible) risk of waiting. We must learn to fight for a fair valorization of created knowledge.

The main weapon in this struggle is the people: the highly qualified, motivated, and socially committed human resources. In the knowledge economy, an important and increasing part of the means of production lies with the people, their training, skills, and attitudes. A large mass of scientists and technicians who are competent, motivated, and above all, socially conscious and committed to Cuba and socialism can be the leverage that in the new economy reverses unequal exchange terms and generates a net North-South resource flow for the benefit of our society. Under capitalism's game rules, and especially in this stage of neoliberal capitalism, talent flows to where the money is. What we need to accomplish is that money flows to where talent is.

MARKET FAILURE

Market failure is a term that some theorists in capitalist economics utilize to identify social phenomena wherein the market cannot direct an optimal allocation of resources. At the extremes, neoliberal fundamentalism does not acknowledge that market failure occurs and wants the market to decide everything. But economists

who reach such extremes of simplicity and mediocrity (or bad faith) are declining in the face of the impossible to hide evidence from neoliberalism's real results.

Many capitalist theorists recognize market failure areas where the state must intervene but limit them to social sectors such as education, culture, some aspects of social security, and other related areas. They continue to be convinced (and try to convince) that, regarding material production, market mechanisms (with their short-term profit priority) are superior in ensuring the optimal distribution of resources and that private interests will someday generate the enrichment of all. Even leaving aside the moral blindness of this approach (which is reason enough for critique and rejection), we can now see how this ideology has ceased functioning even in the realm of production.

The scientific-technical revolution begins to expand the sectors we have called the knowledge economy, where:

- Knowledge is the chief input of the productive process. This socially generated knowledge is impossible to privatize and is not limited to the technological instructions of a given process but extends to the workers' culture and creativity.
- Workers are the company's main asset, including their knowledge and motivation. Human resources can no longer be treated as variable capital and must be protected even in unprofitable periods.
- An important part of economically relevant knowledge is tacit, non-structured (and therefore non-negotiable) knowledge, as well as knowledge inserted in the complex system of internal relations of productive organization beyond individuals, which makes it transferable when people move or "brains are drained."
- Generating new products is not the exception, but the quotidian life of productive organization. Companies must internalize research and product development and pay attention to the long term.
- Cooperation among different productive organizations generates

knowledge recombination and works better than competition as the engine of labor productivity.

Can the market accomplish all of this? Our hypothesis is that it cannot. As knowledge economy sectors expand until they occupy a larger part of economy and commerce, and as their features penetrate all sectors of conventional economy, capitalism's fundamental contradiction between the social character of production and the private character of appropriation will become more acute and unsustainable. And the market economy itself, praised by those who hold the resources, will progressively curtail the development of the productive forces, just as Marx anticipated. The market failure zone will expand from the social to occupy more space in material production and commerce.

Capitalism, with its short-term orientation, may exhibit immediate profitability advantages in a traditional economy, advantages that it can attain by sacrificing human development, social justice, and the environment, but the progress of the productive forces toward a new type of economy will gradually erode these advantages. Some evidence of this process can already be seen in the stock market crashes of high-tech companies in industrialized countries. More than 80 percent of biotech companies created in the 1980s and 1990s did not become profitable by sales and have depended on financial engineering to keep operating. Some North American high-tech companies survive thanks to military spending, which leads to the monstrous absurdity of using war as a stimulus for the economy. Financing scientific research and technological development with military funds (seen in many developed countries and especially the United States), besides being a symptom of the dangers that the ideology prevalent in world capitalism's power circles creates, is also a symptom of the increasing incapacity of the market economy to insert scientific knowledge rationally, efficiently, and peacefully into the fabric of society's economic relations.

Socialism is better prepared for the knowledge based economy.

How else to explain the biotechnology sector's emergence, expansion, and profitability in Cuba in an economic conjuncture as unfavorable as the Special Period in the 1990s? We will have to keep studying this experience in the context of medicines and vaccines, that is, in the type of productive organization the former generated, which to some extent foreshadows what will be the state socialist, high-tech company in the future Cuban economy.

TOWARD THE STATE SOCIALIST HIGH-TECH COMPANY

In the practical task of developing the biotechnology sector of the Cuban economy, and as a consequence of the concrete decisions we have taken, a new type of productive organization has emerged. It is not a conventional company like those in other sectors. But it is not a scientific center like those in the science and technology sectors. It does not fit into either of the two schemes, and it would be an error to try to mold it into either of them. Like any other company, these biotechnology companies must produce, commercialize, and contribute to the national economy. Besides, as with any high-tech industry, a very high added value (in proportion to its high knowledge content) is expected, and this must be expressed in low operational costs by weight, below 0.5, and high labor productivity per worker. Also, like other entrepreneurial sectors, this new sector must grow, that is, function within a cycle of enlarged reproduction of material production. It is already a part of the national economy and one of the main sources for the expansion of the exporting capacity of our country with nontraditional lines. The December 2003 report by the Ministry of Economy and Planning to the National Assembly of People's Power clearly expressed this idea.

But, unlike many other companies, Cuban biotechnology organizations internalize scientific research, even basic research, and their results are also measured by knowledge production. Besides, they have other social duties (in addition to economic profitability). The most obvious of them is that, through the

companies' exports, they finance the foreign currency costs of the health system. But there are other duties, like, for instance, the work of the Immunoassay Center in maintaining and developing a national network of laboratories for perinatal diagnosis, epidemiological surveillance, and blood safety, or the work by the Neurosciences Center in the social programs for the disabled. In many other cases, Cuban centers are the main actors of national health programs, as is the case with the vaccination, AIDS, cancer, and hepatitis programs, among others.

Scientific institutions are expected to build and expand collaborative networks with other scientific institutions and higher education centers. Many are already higher education teaching units. They are a source of employment for highly qualified labor, and if the system continues to expand as expected, will function as a higher education locomotive, creating unbudgeted jobs that directly contribute to the national economy. In each of these organizations is a closed research cycle, the development of products and processes, and commercialization. They maintain two international relations activities: entrepreneurial, through exports, negotiations, and mixed companies abroad, and academic, with the international scientific community.

All of this activity must be (and indeed already is) economically sustainable through the income of each organization, and it has to contribute resources to the country's economy. It also occurs in the framework of a socialist state, as property of the Cuban people and an expression of the principle inscribed in our constitution of social property over the fundamental means of production. This kind of productive organization, which is neither a company nor a scientific center in their traditional senses, will require a tailored design regarding its financial schemes, management systems, and improvement.

This is certainly a new type of productive organization, but it is not an exception, nor should we treat it as an economic singularity. Quite the contrary: as the country increasingly enters the knowledge economy, we will see the increasing emergence of this kind

of organization, with research, production, and export cycles, in other sectors of the economy. Some of today's companies will progressively internalize scientific research and assume a dynamic of new product generation and external competition by high-knowledge product differentiation, whose internal structure will look more like today's centers of research production. In fact, this kind of productive organization will eventually become the main tool to articulate science and the economy and the catalyst for expanding the knowledge economy and scientific research.

The existence of companies that internalize, at least partially, the generation of knowledge and that, as a consequence, develop a greater absorptive capacity of knowledge generated by others will develop within some territories the embryo of local innovation networks that launch a cycle of mutual fertilization among companies, scientific institutions, and universities, the latter being present in all municipalities. The first indication of emergent phenomena of this kind can be seen in some municipalities, as evidenced in Yaguajay's socioeconomic development program, which will be addressed in the next chapter.

LEADING THE TRANSFORMATION

Socialism is the conscious direction of society. Humanity ceases to be history's passive object and takes control of the rudder as a conscious subject. This concept also entails a responsibility. Neoliberal ideology holds that market forces will improve the indicators of economic productivity, which will later generate improved social indicators. Experience has proved this assumption false. However, it would be naïve of us to suppose that the investment we are making in education, culture, and in our human capital, with fairness, solidarity, and altruism, will spontaneously lead to the articulation of science and the economy and the development of material production based on high-tech knowledge. It will undoubtedly happen, but the process is not spontaneous. We must direct it. The creation in 1980 of the Scientific Pole of Biotechnology was a

concrete expression of this conscious direction. The more recent creation of the University of Informatic Sciences is another one.

The efficient connection between science and the economy does not occur automatically; it requires conscious direction and strategy. The tragic experience of the European socialist countries, which built good science, proves that failure is possible. The Cuban experience demonstrates that even starting from a context of industrial underdevelopment, under economic blockade conditions, and under imperialism's paranoid hostility, it is possible to succeed. Our strategy considered the need to develop highly qualified, motivated, and committed human capital on a massive scale. This educational process is not a distal consequence of economic growth but a requirement. The Cuban strategy includes bringing higher education to every territory where the real economic life of the country takes place. We also have recognized the need to create new organizing forms to catalyze the integration of scientific research with producing goods and services. The biotechnology centers of research production and the technological park project at the University of Computer Science are expressions of this commitment.

The biotechnology sector must keep growing, especially now that it is possible to finance growth from its economic performance. We will have to assess in detail the successes and errors of all the experiences and extract the conclusions that allow us to continue building and reinforcing the links among scientific research, knowledge management, and the economic performance of our state, socialist production and services companies in all economic sectors, and extend these links to our external trade.

These conclusions will no doubt touch on such aspects as the funding of scientific research, the management of human resources in the high-tech sectors, the research and development components of the structure and financial systems of companies, the adequate management forms for this new level of development of the productive forces, and the negotiation strategies concerning our technologies, among others. All of this is in the context

of socialism and social property over the means of production, where our main advantages lie.

CHAPTER 5

The Knowledge Economy and Socialism: Reflections from Yaguajay

I have discussed the main conclusions from Cuba's biotechnology sector about the integration of knowledge production (science and technology) into the value chains of productive organizations and the particularities (and comparative advantages) of this process in the context of socialism's relations of production.[1]

This chapter on territorial development continues the discussion.[2] In the difficult 1990s, I participated in another experience, the emergence of socioeconomic development projects in the rural municipality of Yaguajay. These projects also were based on knowledge management and the interaction of municipal entities with the science and technology units. The fundamental finding from these projects was that many experiences converged with those of the large biotechnology centers. This allows us to understand both experiences as different expressions of a single underlying process, namely, the new role of knowledge (and knowledge management) in economic systems and the dependency of this process on the sociopolitical context in which it occurs.

I will then try to take the reader along the route I traveled, starting from the description of Yaguajay's projects, to first identify

their particularities and their similarities to other experiences of the knowledge economy, and intuit how we can reinforce and accelerate these processes in Cuba by deploying the enormous economic development potentialities contained within socialism. The reader is forewarned that I am not an economist or an expert in these topics, but only a comrade who, because of circumstances, had the opportunity to simultaneously participate in both socio-economic experiments (biotechnology and the Yaguajay Project), which allowed me to make certain observations that I now feel compelled to share.

KNOWLEDGE ECONOMY: THE ESSENTIAL AND THE PHENOMENOLOGICAL

The term "knowledge economy" began to be used widely in the 1980s to describe new phenomena, such as the growth of industrial sectors (microelectronics, software, new materials, biotechnology, telecommunications) that constantly generate novel products with a high knowledge content incorporated into their price, where the access to knowledge is the main determinant of competitiveness, and where competition tends to revolve around product differentiation rather than scale and costs. Additional features of a knowledge economy include the massive use of computing by industry, the expansion of the service sectors together with the joint reduction in labor power directly employed in manufacturing, price increases in knowledge-intensive services (such as education and health), with the ensuing relative reduction in the price of manufactured products; the need for increasingly qualified labor power; the increase in transactions on intangible assets (patents, brands, technology); and others. All these factors announce the growing role of knowledge generation and exploitation in creating wealth and well-being.

There are two essential processes underlying these phenomena. First, there is the integration of scientific research as a component of the value chain of productive processes, which forces

companies to internalize scientific research and technology development as part of their quotidian activity and expenses. This direct link between science and production results from the constant reduction of the time that elapses between innovations and their application. The second process, derived from the first, is the need for workers' greater and increasing qualifications, motivation, and creativity, which creates a second direct link between productivity and the determinants of human capital: education, culture, and health.

Connections between the generation, circulation, and use of knowledge and productivity have always existed. What is really new, from the late-twentieth century on, is the immediacy with which these links occur and the expansion of their influence on the productivity of economic systems. Identifying these essential processes allows us to see that they are not exclusive to high-tech sectors—computing, telecommunications, biotechnology—but, in fact, they extend knowledge's influence to all production and services, which will become increasingly evident as the twenty-first-century proceeds. Understanding this reality has enormous practical implications. The Yaguajay development projects exhibit various common features with the development of biotechnology in Cuba. These similarities exist in the processes of knowledge management.

CONCRETE EXPERIENCE: THE YAGUAJAY PROJECTS

The municipality of Yaguajay, located in the northern part of the Sancti Spíritus province, has an area of 1,041 square kilometers (about 401 square miles), a little more than 59 thousand inhabitants, 34 percent rural population, and predominantly agricultural economic activity. The socioeconomic development projects were conceived and implemented sequentially starting in 1994. But before describing them, three clarifications are necessary:

- These projects do not occur in isolation but in the context

of a national effort to build the socialist society we aspire to. And they were not created from scratch but are based on the solid human capital and values created by the Revolution over decades. Yet, Yaguajay's experience has innovative elements that distinguish it nationally and justify its specific study.

- These projects crystalizing into a municipal socioeconomic development strategy did not actually emerge from an integral, long-term strategic design, which was impossible in 1994. The real story is that they emerged individually as a response to specific problems and opportunities. Later, the links among them began to be created, leading to a qualitative change in our vision of territorial development, which we can date to 2001. This process continues today.
- Let's not forget the tremendous complexity of the year 1994, in which the economic crisis provoked by the dissolution of the USSR and the European socialist bloc, together with the strengthening of the U.S. economic war against Cuba, created a situation whereby the Gross Domestic Product (GDP) of our economy decreased by more than 35 percent, the Cuban peso was exchanged for 150 per dollar, we had sixteen daily hours of power cuts, per capita calorie consumption dropped below 1,800 and that of protein below thirty-six grams. These were just some of the impacts of the Special Period. For these reasons, we will analyze socioeconomic development projects that arose from the most complex conditions imaginable in a time of peace.

During this period, Fidel Castro spoke of a commitment to "Resist, Overcome, and Develop" [*Resistir, Vencer y Desarrollarnos*], expressing that socioeconomic development is integral to resistance. Yet, we knew this would be a period different from what we had previously designed. Development would still be irrevocably socialist. But now we had to design and carry it out by ourselves, without the economic integration to the socialist bloc on which we previously counted.

The first Yaguajay experience was in health. In the history of the Cuban Revolution, health (along with education) was never considered a distal consequence of economic development, as other developmental models propose. Rather, it was assumed, in theory and in practice, as a human right to be immediately exercised and as a precondition for any feasible attempt at economic development. We shall see the enormous consequences of this idea regarding the transition to a knowledge economy. Thus, the construction of the health system, with free and universal access, and the struggle to improve the health indicators inherited from neocolonial capitalism were among the first tasks of the Revolution in the 1960s.

The moment we set for studying Yaguajay's projects (1994) is also a special moment for public health development in Cuba and the world in two different planes. In Cuba, the question of whether the excellent health indicators achieved during thirty years of socialist construction could resist the onslaught of the Special Period's economic crisis. Cuba had positively distanced itself in its health indicators relative to countries with equivalent economies. Now, the Special Period would test the robustness of our indicators. The early 1990s also was a special moment for global public health. It was when it began to be understood that most countries would not achieve the World Health Organization's (WHO) goals of "Health for All by the Year 2000." The public health crisis, conceptualized as an increasing disconnection between population health needs and expectations and socially organized responses, began to be discussed. This crisis has hampered many countries from achieving the WHO goals.

Amid these conditions, the Yaguajay Health Project sought, through its measurements and interventions, to go beyond disease treatment and risk approach to the field of positive health, in congruence with WHO's (1948) foundational health definition: "Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."[3] The idea of positive health compelled us to delve into such topics

as population physical and intellectual performance, nutrition quality, social cohesion, and family nuclei functionality, among others, which in turn imposed a multi-sector focus, with tasks not only for the health sector, but also for culture, sports, and education organizations, as well as territory companies and the Popular Councils. Only the municipal government could direct an effort at this level of integration.

This approach required an enormous training, advising, and knowledge management effort, given that most protagonists lacked prior training in the strategy. In addition, surveys yielded new health indicators, and interventions to modify them were designed and implemented. Various institutions of the MINSAP (Ministry of Public Health), especially the Hygiene and Epidemiology National Institute and the Nutrition Institute, advised the project.

The analysis of the evolution of Yaguajay's health indicators, and of resistance or vulnerability to each of them, and the efficacy of each intervention, will require a broad study. Let us limit ourselves to noting that results have been obtained. Thus, between 1995 and 2002, general mortality decreased from 8.2 to 7.2 per thousand inhabitants; the proportion of the population over fifty years old increased from 23.8 percent to 27.9 percent; low birth weight was reduced from 8.1 to 4.1 per every thousand live births; breastfeeding increased from 61 percent to 83.3 percent; the functional family indicator rose from 85 percent to 92 percent; the sedentary index decreased from 37 percent to 14 percent. The prevalence of hypertension also began to decrease.

I do not aim to discuss the meaning of each of these and other indicators. Our interest is to underscore that Yaguajay's Health Project, with its positive health approach, had a multiplying effect that gave rise to other projects to address problems related to nourishment, employment, housing, and the environment. In the realm of food production, we received advice and technologies from the National Center of Laboratory Animals, the Center of Genetic Engineering and Biotechnology, the Research Institute on Tropical Agriculture, the Cuban Institute on Sugar Cane Byproducts, the

Swine Research Center, the Poultry Research Center, and others. Objectives were set to increase meat production (bovine, ovine, goat, swine, rabbit, and poultry). Today, there are more than thirty-three projects in the agricultural sector. The projects were complemented by recovering pork production, constructing new dairies, developing meat and buffalo milk production, a forest development project, and other tasks.

For tourism development, we were advised by the Science, Technology, and Environment Ministry and the Ministry of Tourism. We conceived a strategy based on the ecological, archaeological, and historical wealth of the municipality, including the improvement of tourist attractions in Villa San José del Lago and Caguanes National Park, as well as the development of new ones to capture a market of visitors based on the available room capacity or plans in Cayo Coco, Cayo Santa María, and Trinidad. This scheme of low initial investment seeks to capture more specialized and sophisticated tourism, which in turn induces the development of labor power within the municipality for this activity.

For housing, advice was sought at the Technical Center of Construction Materials and Las Villas Central University to create a workshop on low-energy consumption using extant materials in the municipality. During this period, albeit not because of the workshop but because of other national and local efforts, the number of homes classified as in good condition rose from 45 percent to 68 percent, and the number of electrified homes increased from 96.2 percent to 98.1 percent.

Computing proved to be a highly catalyzing project. Advised by the Ministry of Informatics and Communications and the health informatics network INFOMED, we began to create, in the mid-1990s, a territorial network that today includes more than 250 computers and more than forty email spots that link the municipal government with companies and other territorial entities, national networks, and a municipal portal.[4] A Geographic Information System also began to be incorporated. Today, Yaguajay is one of the municipalities at the forefront of "computizing" society.

Training managers in the municipality received special attention in these projects. The Ministry of Higher Education advised this task. A total of 394 senior managers and their entities in the municipality participated in formal training activities from 1966 to 2003. In 2002, this group's experience enabled the transition to a higher stage, the construction of a municipal development strategy, for which a managing group led by the Provincial Administration Council was constituted. This group produced an analysis and defined actions and objectives in three main areas: industry, agriculture, and tourism. The program sought, among other things, to maintain a 30 percent annual increase in commodity production and to attain a cumulative growth of 50 percent by 2006.

THE REGULARITIES OF YAGUAJAY'S PROJECTS

Regardless of the particular elements of one or another project, in Yaguajay's projects, we can identify eight common traits.[5]

1. Project design: all projects started from a diagnosis of the area, with quantitative measurements and objectives to achieve and actions leading to achieving objectives. It is no coincidence that one of the main and most intense training actions for the municipality's cadres was project leadership. Directing a project is directing a transformation. That is exactly what the cadres learned to do and did.

2. Knowledge management: all projects incorporated novel technologies. Knowledge and the necessary technologies existed in the country, in scientific centers, universities, or companies for most projects. Yaguajay's projects simply and quickly built connections and catalyzed the circulation and use of accumulated knowledge.

3. Advice by Science and Technology Units: knowledge and needed technologies were sought where available in the more than two hundred Units of Science and Technology (UCT) in the country or a university. An inversion of the traditional model for results

introduction occurred, which places the UCTs as central agents in the search for territories or "introducer" companies. A model also emerged where local government was central to exploratory work and links with the UCTs or universities where the required knowledge is found.

4. Training: between 1996 and 2002, 181 training activities were carried out in courses, workshops, and conferences involving more than eleven thousand people (in a municipality of sixty thousand inhabitants). In some cases, permanent institutions were created, such as the Technological Development Unit of the Livestock Company, Fifth Congress [Unidad de Desarrollo Tecnológico de la Empresa Pecuaria V Congreso]. This intense training entailed special attention to governmental managers and their different sectors and state companies. They are the backbone of the Revolution, as Che characterized them.

5. Multi-sectoral: projects were identified by their objectives, not by the organizations or sectors managing them. Thus, an objective such as increasing the nutritional levels of pregnant women wasn't confined to the health sector, and building tourism on the ecological, archaeological, and historical values of the municipality required the participation of various sectors.

6. Participation: the Yaguajay Project is known to the people. It has been explained and discussed in companies and the Popular Councils. Popular participation did not occur only as a transmission mechanism but from the construction of projects.

7. Municipal government guidance: multi-sectoral and participatory projects of this sort, which heavily rely on connections between diverse social actors, can only be guided by the people through their representative in exercising power: municipal government. It cannot manage everything, but it has an irreplaceable function as a facilitator and supervisor, identifying opportunities and distortions, guaranteeing the maximum potentiation among seemingly distant actions and actors, and coherence between a province's and the country's strategies. In fact, the municipal government works as the main catalyzer of the interactions among

scientific centers, teaching entities, and companies. In Yaguajay, this function included the creation of the municipal government's office of projects as an advisory group to the president.

8. The emergent role of the Municipal University Seat: since its emergence, the Municipal University Seat in Yaguajay has become a leading actor in socioeconomic development projects. Its training and knowledge dissemination functions are expressed through the massive development of human resources and in the training of managers, in the participation of professors in the debates and analyses of the municipality's socioeconomic development and its companies' development projects, and in the postgraduate, adjunct, and tenured professors' research plans. The creation within the Municipal University Seat of a Municipal Economy Analysis unit (with eight professors) is a concrete expression of this function.

The Municipal University Seat is set to become the chief teaching and scientific institution in the municipality, in the "constructor of connections" for the circulation of knowledge among the municipality's institutions and other territories, including the scientific centers of national character, and in the main advisor to the government for the expansion of the knowledge economy in this territory. The transition to a knowledge economy has an important cultural dimension that may well become the determining factor of the velocity of the general process.[6]

The reader now has an overview of the Yaguajay municipality in terms of numbers and facts. I will try to interpret them through the lens of current ideas about the knowledge economy and identify the opportunities and challenges posed by taking advantage of these opportunities.

YAGUAJAY'S PROJECTS AND THE KNOWLEDGE ECONOMY

Often when we think of the term "knowledge economy," we make a mental connection to biotechnological laboratories, computer factories, or internet companies. But if we can evade the trap of

confusing form and content, we will see that the essential elements of the knowledge economy are present in Yaguajay's projects. They are:

- Rapid technological changes in companies.
- Companies' economic viability dependent on new products (diversification and product differentiation).
- Development of products of higher added value.
- Connections of companies with universities and research centers.
- Permanent presence in companies of transformation projects, requiring that directors pay attention to project leadership in addition to basic processes of production and services.
- Need for intense and continuing training of all workers, especially managers.
- Generation of new knowledge (frequently generalizable) within the companies, expressed in the most advanced cases via the emergence of research and development strategies.
- Systematic activities of "knowledge circulation" within and among companies, and between them and teaching and scientific institutions, in and outside the territory.
- Development of quality assurance systems in all companies as a way to capture and structure new knowledge.
- The increased use of information and communication technologies throughout Cuban society.

This is about essential processes similar to those we have seen unfold in other sectors, such as biotechnology, but that we now see in the livestock industry, various crops, housing, tourism, communal services, and many other sectors. Understanding this reality allows us to see enormous opportunities. The knowledge economy is not a phenomenon exclusive to certain sectors and institutions but a transformation that can and must penetrate all productive and service sectors within all the territories in the country. Several countries of the Global South have experienced failures

in establishing large scientific research institutions, even though they were well equipped and had skilled personnel. These institutions were juxtaposed to, but not integrated into, their societies. They interact with their counterparts in the North, frequently with good academic results, but they have not been able to transform the generation, circulation, and use of knowledge in underdeveloped countries. The existence of such institutions, in principle a good idea, is a necessary, but not sufficient, condition for socioeconomic development.

THE KNOWLEDGE ECONOMY AND SOCIALISM

In a previous chapter, I argued that as the economic sectors where knowledge is the principal input of reproduction, and the production of services expands, capitalism's fundamental contradiction between the social character of production and the private character of appropriation will become more acute and unsustainable.[7] The market economy will impede the development of productive forces, just as Marx foresaw.

Knowledge, increasingly the chief and determinant input of competitiveness, provokes a predictable attempt by capitalism to privatize it through the creation of intellectual property and technical barriers and by increasingly concentrating the scientific research institutions in fewer hands, which generates enormous transaction costs and contradictions in the process of knowledge circulation and recombination. These will ultimately become a barrier to technological progress. At present, the speed at which new knowledge is generated exceeds that at which every new piece of knowledge or technology can be exploited in sectors or institutions other than those from which it emerged. This creates a potential creativity vis-à-vis "knowledge recombination" and technologies from diverse, even distant fields and institutions. To pretend this will occur through market relations among "proprietors" of each piece of knowledge will increasingly entail sacrificing efficiency for the sake of private property.

It becomes ever more evident that in the knowledge economy, cooperation is more effective than competition. To the general contradictions arising from attempts to privatize knowledge must be added the neglect of social investment, typical of neoliberal capitalism, at the very moment in which education, culture, and health are more and more directly linked to economic growth.

As the production and accumulation of knowledge become the main tendency in developing the productive forces, the classical distinction between social investment (oriented to the long run) and investment in economic sectors that seek direct and immediate returns ceases to make sense. The distinction still exists, but it will become blurred. In Yaguajay's experience, implementing a health project–created developmental needs and connections with other productive sectors. Computer science, the protection (and use) of the environment, employment, and other processes point to the new role that the so-called social sectors acquire as catalysts of economic growth.

For many countries, the lack of human capital and the climate of cooperation and social cohesion (which some call "social capital") will become the main obstacles to the transition to a knowledge economy. Speed is an issue in this transition. The speed of technological development generates a demand for human capital at such a rate that a training need identified ex post facto will not be able to keep up with it. Only a prior and accumulated effort in education, culture, health, and science can guarantee that human capital becomes available to respond to opportunities and needs that are hard to foresee. Even the most industrialized countries face this contradiction, which is directly derived—even if they refuse to admit it—from capitalist relations of production. There is an ongoing attempt to solve this issue through the pillage of the new limiting resource, expressed in the brain drain policies implemented by various industrialized capitalist countries. They might obtain a palliative for the problem but not a solution, requiring profound social transformations they cannot undertake.

All of these conclusions, which we have drawn from Cuba's

biotechnology experience, become ever more evident when we analyze Yaguajay's experience as an embryo of a knowledge economy at the territorial level. The specialists and necessary managers for Yaguajay's projects were mostly already there, as were the workers' cultural development and motivation too. There also were scientific centers and universities advising the projects. Above all, the Cuban Revolution had decades of experience in developing human capital and social consciousness. That process has entailed cooperation, commitment, and integration among all social actors, together with the experience of popular power [poder popular].[8] Cooperative activities such as those in Yaguajay, among Science and Technology units (Center for the Production of Laboratory Animals, Cuban Institute of Sugarcane Derivatives, the Genetic Engineering and Biotechnology Center), the territory's universities and companies (the agroindustrial sugar complex [SAC], various crops, livestock) all would have been impossible in the context of market relations and competition for profit.

CHALLENGES AND OPPORTUNITIES

Socialism's relations of production are far better equipped than neoliberal capitalism to respond to human capital needs, circulate knowledge, and ensure the social integration and participation essential for the transition to a new economy. The movement to knowledge-based economies in the most advanced economies is an opportunity for Cuba. We have decades of experience in human development, social equality, and the consolidation of socialist relations of production that have yielded good results in several realms, including the biotechnology sector.

It is worth remembering here that Fidel Castro declared in January 1960 that the future of our nation must be a future of science, before the Literacy Campaign. The creative work of the Revolution has been consistent with that idea, beginning with universal access to education, the proliferation of universities and scientific centers, the innovations of the workers' movement

(National Association of Inventors and Rationalizers, ANIR), the Youth Technical Brigades, and the Science and Technology National Forums, to the investments in biotechnology in the 1980s and 1990s, and the establishment in 2002 of the University of Informatic Sciences, a research center in Havana.

But opportunities always go hand in hand with challenges we must face and overcome. We must bear in mind the negative experiences of grafting a science unrelated to the economy in several countries in the Global South, the plunder of human resources via the brain drain, and the technological delays in the USSR in some sectors despite undeniable academic excellence. The first task is to understand these challenges. The experience of the Yaguajay projects has allowed us to identify several.

1. *The knowledge economy entails a permanent process of innovation, trial and error, and new products and technologies*. This requires that successful experiences receive feedback directly through the production and finance surpluses they generate. This is the only way to know if something really works. In the biotechnology sector, the creation of whole-cycle centers, that is, of research-production-commercialization, under the difficult conditions of the 1990s, allowed for economically positive experiences (even small ones) to be reinforced (with resources) and not diluted in general balances. This whole-cycle approach should be implemented in other sectors, with careful analysis of the institutions exhibiting conditions conducive to it and with close supervision of the experiment.

We should also bear in mind that, in many cases, especially when it comes to innovative products, we will have to complete the economic cycle in the external market, not only domestically. Cuba has a small domestic market, and small markets generally do not demand nor financially sustain much innovation. The space for financing development from innovation lies chiefly in the export market. Besides, the successful development of exports will allow us to guarantee access to the products of innovation to our people in conditions of total coverage of the given need and equality,

implementing in practice the critical concept that the Cuban people are not customers but the socialist owners of our companies. We will have to create direct links between those innovative companies exhibiting the appropriate conditions and the external market and uncouple them from producers that impede this link.

2. *Absorptive capacity of technology in companies*. We will increasingly have more companies or groups doing their scientific research in the future. But at present most technologies and ideas for new products needed by companies have not emerged in them but in scientific centers, universities, or other companies. Experience indicates that the simultaneous existence of a need and technology are not sufficient conditions for innovation to be implemented. The company must have the capacity to identify, assess, adapt, and improve the ideas that are proposed to it. This is what we call the "absorptive capacity of technologies." In the past, we tried to solve this problem through the innovation generating centers with results simply presented to the companies. This is important and necessary, but it does not suffice either, for this setting considers the company as a passive, receptive entity when it is the main agent for completing the economic cycle of innovation. We will have to explore ideas such as the creation of development departments within companies, the periodic rotation of companies' specialists and managers by scientific centers, the (non-executive) participation of university scientists and professors in direction councils in certain companies, among other ideas that arise, and retain those that work best. This conscious creation of connections, either from production units in scientific collectives as in biotechnology or from development units in companies, like Yaguajay's livestock company, will make the high-tech, state socialist company emerge.

These companies will be innovative, export-oriented, economically viable, and the property of the Cuban people. They also will be the main actors linking science and the economy and in the transition toward a knowledge economy. Besides being a productive organization, this new kind of company will also be a learning organization, where workers receive training throughout

their entire working lives, and directors assume responsibility for managing knowledge just as they are responsible for managing productive and economic processes.

3. *The tasks of the scientific sector*. Today Cuba has a set of institutions that comprise the scientific sector. Although the sector will continue to exist, its functions will evolve as scientific research increasingly becomes a structural component of all other economic sectors and is increasingly realized in them, including individual companies. The articulation of science and the economy is, and will increasingly be, the main mission of the scientific sector.

This mission will be realized through the following tasks.

1) *The construction of knowledge circulation links through identifying connection opportunities among generation and use nodes at the national and territorial level*s. In this dynamic of knowledge management at the territorial level, an actor of tremendous potential has emerged: the municipal university seat.

2) *The creation of a promotional and regulatory context for negotiations (mainly international) based on intangible assets and the creation of funding streams for scientific activities*. The global tendency in knowledge economy is toward commercial transactions based on the value of a patent or a technology or in predicting a project's value, characterized as intangible assets. In Cuba, we have created much value and can create much more. But creating value is one thing, and realizing its economic benefit is another. Negotiation based on intangible assets will be inevitable, but scientific companies and institutions should not be alone in these negotiations but rather backed by the state as a regulatory power that ensures that negotiations occur under the fairest and most advantageous conditions. The current polemics concerning Cuba's intellectual property law reflect the complexity of this process. We must also guarantee that protecting our intangible assets in international transactions does not complicate the circulation of knowledge and technology among our state institutions at home.

3) *Management of scientific institutions engaged in basic science or high-risk innovations*. This requires protection from pressures to

complete the economic cycle. We must also bear in mind that the changes generated in today's world by the development of productive forces are accelerating. This can compress what "long term" means and introduce, in a generation, the level of change that hitherto occurred across many. What today are long-term decisions may become urgent measures.

4) *The supervision and global evaluation of the entire process of scientific-technical development and its interaction with the economy is a science in itself*. The twenty-first-century knowledge economy is a global phenomenon in which the success of local actions increasingly depends on comparative advantages relative to what occurs elsewhere in the world, which is an even more pressing reality in an open economy like ours.

5) *Centralization/decentralization equilibrium*. A knowledge economy presupposes decentralized economic management that enables companies and territories to explore product and technological alternatives, innovate, and reap the benefits of their innovations. Economic management capable of coexisting with constant technological change and the short life cycle of products and services and that also learns by trial and error at the local level is a must. The epoch of massive production and standardization is gradually abandoned as an objective consequence of developing productive forces. These new phenomena also demand innovative administrative approaches. Such decentralization is perfectly coherent with socialism as long as we remain committed to the principle of social property over the means of production and the socialist (and increasingly communist) distribution of the results of production.

Social property and centralized administration are not synonymous, and the experiences of other countries that tried to establish socialism demonstrate unfortunate errors vis-à-vis this relationship. And this in both senses: first as when, as an incorrect and unnecessary consequence of social property, bureaucracies that limited the evolving capacity of the economy were created, and second, in the inverse sense, when, in an attempt to make the

economy dynamic, they made concessions concerning the social property principle. The disastrous results of these experiments are well known. The challenge is to build dynamic and decentralized economic management in the context of a system of state property that is not only not coherent with it but becomes the ideal facilitating context for a knowledge economy.

The decentralization of economic management required by the knowledge economy also poses risks. If at the centralizing extreme lies routine, the loss of opportunities for innovation, and the lack of capacity to adapt to change, at the decentralizing one are the inefficient use of resources, the incorrect appropriation of surpluses, and the prevalence of entrepreneurial interests over those of society as a whole. Where is the middle zone of maximum efficacy? What the Yaguajay experience brings to this discussion is that municipal government can be a formidable guarantor of decentralized economic management, along with maximal vigilance and the protection of the interests of the socialist society as a whole.

6) *Direction and evaluation of the process*. The transformation of our economy into one based on knowledge is a process that we cannot leave to spontaneity. We must direct and evaluate it. Socialism is also the conscious direction of society, where people are no longer the passive object of historical processes and become history's conscious subject. We all aspire to that. But identifying and implementing the actions that will lead to a knowledge economy, and the selection of indicators to measure the process, are not trivial decisions but rather very complex challenges. Moreover, the construction of a globally-competitive knowledge economy, from the conditions of an industrially underdeveloped country, has never occurred, so we do not have many points of reference.

Human societies are an excellent example of a complex system in the strict scientific sense of the term. They are full of multiple, non-linear interactions and exhibit many other variables that can generate transitions or regular or chaotic behaviors, whose analysis resists reductionist predictions based on one or a few determinant

factors. But such an understanding of complexity cannot make us renounce society's guidance, for we human beings have, besides our ability to understand, a moral capacity that obliges us to identify what is fair and fight for it. We can know the world as it is, but we must also fight for the world as it should be. What is a "sustainable socioeconomic development" based on knowledge management? How is it directed? With what indicators (obviously not with the classical GDP) should we measure our progress in the right direction? Those are the new challenges.

THE KNOWLEDGE ECONOMY AND NATIONAL SOVEREIGNTY

A visible and dangerous component of neoliberal globalization ideology is the weakening of national sovereignty in the global village and the loss of viability in national states.[9] The danger lies in capitalism's economic globalization occurring without an equivalent globalization of social commitment and ethics. The behavior of rich, capitalist countries is still predatory and unrestrained, for even if domestically, the state has a responsibility (that many nations only theoretically assume) concerning the well-being of all citizens and the reduction of distributive injustices, at the level of global competition among nations, no one assumes such a responsibility, not even theoretically. Hence the twentieth-century galloping process of wealth concentration and people's marginalization. By displacing labor exploitation beyond national borders, imperialism initiates a regressive process regarding social justice matters, for it situates exploitation out of the range of restraints that workers' struggles can conquer within the nations' judicial spaces.

The ideological attack on national sovereignty seeks to remove one of the few barriers against global capitalism's predatory behavior. Undermining national sovereignty will generate greater injustice, environmental destruction, wealth polarization, and marginality. Thus, this ideological attack is profoundly reactionary, not a positive element of postmodernism, as it is often portrayed. The defense of national sovereignty involves guaranteeing the

economic viability of nations as spaces where the enlarged reproduction of material life is guaranteed. Otherwise, there would be no nations, just ethnological reservations and folklore.

On what, then, does economic viability depend? The tendency we are witnessing (still incipient but clearly discernible) is that it depends less and less on natural resources and increasingly on the ability of knowledge generation, assimilation, and use. This is not a complete process yet, and for many years to come, the main determinant of the sovereignty for several nations (for instance, the oil-producing countries) will be the control of their natural resources. But we are not an oil-producing country. Most countries in the Global South are not. In those poor countries (Africa's, for instance), national sovereignty rests on low value-added productive systems, whose viability thus depends on external aid (or tourism), which comes with political conditions.

The role of science and technology as instruments of exploitation during the imperialist stage (or, conversely, as a liberation weapon) is understudied in political texts because the direct link between science and the economy is a relatively recent phenomenon, and there is insufficient historical experience for its analysis. But already, we can intuit that scientific-technical development and its ties with the economy will increasingly become a part of the struggle for equality, independence, and national identities in the twenty-first century. If scientific-technical development continues to be polarized, an equivalent polarization will occur in exercising humanity's economic rights.

This problem cannot be solved only with scientific institutions, as necessary as they may be. The construction of a sovereign alternative of socioeconomic development requires the creation of a productive apparatus capable of rapidly assimilating new knowledge and technologies, adapting and enriching them, utilizing them to increase the added value and the differentiation of their products and services and connecting, through them, to the global economic flows. These capacities must be present in companies; we must expand those experiences that attain a certain performance

in the knowledge economy and increase them in the national economy. They are not a luxury but seeds to fertilize.

In Cuba, the experience of the biotechnology sector demonstrates the economic potential of high-tech research-production-commercialization organizations. But the experience of Yaguajay's projects (and the connections between scientific institutions and the locality's companies) indicates that the fundamental processes that determine the emergence of a knowledge economy can occur in (and be stimulated by) any territory, within state companies and social institutions such as those that we have by the thousands in our 169 municipalities. There is nothing extraordinary about the Yaguajay experience. It can and must be extended to other territories, considering their specificities and the historical moment in which each experience is initiated. In fact, there is already an ongoing experience exchange with other municipalities. This profound debate must be handled very carefully because the point is not to imitate what was accomplished in Yaguajay but to draw from that experience the essential features and underlying phenomena through which the advantages of socialism for the transition to a knowledge economy are expressed, even in a country with low industrialization.

This is an incipient process; there will be much to learn and perfect. There also will be errors to rectify. But it already has yielded experiences that, in our view, can be discussed, analyzed, and criticized. Moreover, and this is most important, the experiences and their comparison with those at other latitudes indicate socialism's enormous potential for constructing a knowledge economy that creates material and spiritual wealth and guarantees (and at the same time is guaranteed) by social justice. Our enemies, even if they do not recognize it, sense this, which is why they stubbornly attack us. It is also the reason why we firmly defend our socialism.

CHAPTER 6

Connecting Science and Economy: The Levers of Socialism

Cuba's biotechnology experience, and particularly that of the Center for Molecular Immunology (CMI), is one of the connections between science and the economy, that is, between knowledge creation and its use for creating value, especially in the export economy. From this perspective, the biotechnology experience contains regularities and offers useful ideas for other sectors of the economy and the more general process of social construction (which includes but is not limited to the economy) to which we Cuban communists are committed.

In this chapter (originally published in a different version in *Cuba Socialista*[1]), I offer some proposals. Readers can assess their validity and how generalizable they may be. If I reference the CMI experience in what follows, it is only a starting point. The ideas here do not come from a theoretical study of the topic but from an attempt to glimpse the essential processes underlying a practical experience.

I will give you a heads-up: the main ideas that will emerge are related to the increasing role of knowledge management in the economic systems of the twenty-first century, with the importance

of linking science and production, the particularities of this task in Cuba, the advantages of socialism to implement this science-economy nexus, and the need for a conscious direction of this relationship, which will require economic and administrative innovation.

THE CMI EXPERIENCE: THE BIRTH OF A "GREAT ENTERPRISE"

Commander in Chief Fidel Castro inaugurated the Center for Molecular Immunology (CMI) in December 1994. The date was the most complex moment for the Cuban economy since the triumph of the Revolution. When the CMI was launched, our collective certainly had an enthusiastic group of good scientists committed to the Revolution and socialism, with interesting ongoing scientific projects. We were equipped with a mid-sized facility for the industrial production of monoclonal antibodies, with acceptable quality standards for the time. But it had only one product in clinical use, a monoclonal antibody for the treatment of patients with organ transplants. With low Cuban and worldwide demand, its productive and commercial experience was minimal and exports totaled less than $100,000 per year.

Within twelve years, the CMI was transformed. By the end of 2006, its exports reached twenty countries (a more than three-hundred-fold increase). They earned tens of millions of dollars. Production saturated the extant industrial capacities, requiring new equipment. CMI factories of joint venture ownership were built in India and China, and the number of CMI patents deposited in other countries multiplied. Last, trade agreements reached Europe, Japan, Canada, and even the United States (the latter with special approvals, despite the blockade).

Several countries obtain all the recombinant erythropoietin (a product for treating anemia) they need from our facilities in Havana. CMI's monoclonal antibodies for treating cancer today reach patients in Latin America, India, China, Canada, Germany, Japan, and the United States. Today, the CMI is broadening its

productive capacities through a new investment allowing it to treat more than fifty thousand cancer patients annually. In 2006, the CMI tied with Cuba-Níquel for the National Exporter Award in "great enterprise."

How did this come from the small scientific groups with which the Biotechnological Front was created in 1981? It would be superfluous and pretentious to say it is because we have the best scientists. We certainly have great scientists, but so do other Latin American countries, yet they have not achieved this biotechnological leap. It would be even more arrogant to say it is because we work harder. Cuba certainly has many comrades committed to their work, but in other sectors of the economy, where similar exports and productivity per person have not been achieved, there are also committed, even heroic, workers, and there are probably more of them.

What is special then, about Cuba's biotechnology?

If we seek to analyze it solely as a scientific experience, we will miss half the story and that half is where the main levers are. We must analyze these centers as economic organizations to discover the mechanisms that have produced these results and those that limit attaining superior results. Those who have worked in the biotechnology sector are politically obliged to carry out this analysis or at least propose it.

Our analysis inevitably has limitations. The connection between science and the economy must be the focus of scientists with sufficient knowledge about the economy (as is the case here), or economists with enough understanding of the proceedings of scientific research. Debate and historical experience will make the synthesis.

THE KNOWLEDGE ECONOMY AS AN OBJECTIVE PHENOMENON

The integration of science and the economy isn't a new phenomenon, but its magnitude is novel. There are two reasons. The

first is the relative importance that the accumulation of technological knowledge vis-à-vis capital accumulation has acquired in constructing and maintaining economic advantages. In the industrial economy of the twentieth century, in which a central set of technologies (oil, internal combustion engines, electricity, steel) allowed massive, low-cost production, the limiting factor for development was, undoubtedly, capital accumulation. Possessing capital meant that technologies and infrastructure could be bought that could guarantee the enlarged reproduction of capital. The introduction of scientific research into industry (through collaborations with scientific centers or the internalization of research in companies) gradually generated new products at an ever greater speed, replacing traditional competition based on large-scale, low-cost production with product differentiation, novel products with high added value, which depends on the amount of knowledge incorporated into costs and prices.

At a given time (different for sector and country), the speed of product substitution and their added value was such that capital availability became insufficient to maintain competitiveness. Thus, it became essential to have new products and technologies and, moreover, to have the capacity to permanently develop new products and technologies from knowledge creation.

The power relationship between capital and knowledge may tend to reverse, and if the twentieth-century industrial economy had the capital to buy the needed knowledge, today, whoever has the knowledge can increasingly mobilize the needed capital. This relationship differs among sectors, and it is still incomplete, but it is already estimated, for instance, that in the informatics sector, more than 70 percent of sales are products that have been on the market for no more than two years. In certain high-tech sectors such as computing, microelectronics, the pharmaceutical industry, biotechnology, nanotechnology, and telecommunications, these phenomena are all the more evident. But these sectors, to varying degrees, gradually permeate all others.

Purchasing technology becomes less viable because, in the time it takes to implement the acquired technology (or the novel products it generates), it most likely has been replaced by a better one. The only guarantee is that human capital can creatively assimilate and generate new technologies. We will return to this topic to link it to the "brain drain."

The second reason for the increasing integration of science into the economy is related to globalization. This is a multifaceted phenomenon, and I will refer mainly to some of its components, like the increasing global circulation of capital and products and the reduction of export transportation costs. This makes it possible to think of producing "for the planet" or for a substantial part of it and not only to satisfy national demand, which in turn makes massive production possible. Large-scale production is tightly linked to the science-economy nexus. When a company internalizes scientific research among its activities to obtain new products and the complex quality guarantee systems needed to make them viable in the market, these activities become a fixed cost in the economy or company, that is, activities that have to be financed independently of the company's sales volume. Thus, the high productive volume and sales from global (or at least multi-country) operations makes it possible to subsume the fixed costs of research and quality control and transform them into an advantage for enlarging the volume of operations. Without economies of scale, the current internalization of scientific research in companies would be impossible.

Although rapid substitution of products, value-added products, scientific research internalization by companies, and the need for highly-qualified labor power, among features of the knowledge economy, are more visible in high-tech sectors, they also occur in other sectors such as the food industry, the construction materials industry, and tourism. Thus, what we are discussing here is of interest to not only scientists. It is about objective phenomena, and opposing them would be as absurd as the nineteenth-century Luddite movement's opposition to industrial machinery.

THE KNOWLEDGE ECONOMY AS A POLITICAL PHENOMENON

In this section, we will briefly return to some ideas, previously developed articles, that are essential to analyzing the Cuban situation.[2] The increasing connection between science and the economy does not occur in a political vacuum but in the context of global neoliberal capitalism. We learned from Marx to see in capitalism a fundamental contradiction (genetic malformation) between the social character of production and the private character of appropriation. Marx described the primary accumulation of capital as "the historical process of divorcing the producer from the means of production."[3] Capitalism always has privatized the means of production, sometimes violently, sometimes through apparently legal processes. This occurred with the privatization of the land in the eighteenth century and industrial property afterward, leaving workers with no option other than to sell their labor power.

We now see that the increasing connection between science and the economy and the transformation of knowledge into an essential production factor are accompanied by attempts, through several means, to privatize knowledge. Note that although the increasing function of knowledge in the economy is an objective phenomenon, its privatization is political.

The forms of knowledge privatization are diverse and not always evident. The most visible is so-called intellectual property, which is judicially expressed in patent laws that, since 1995, have been universally required by the World Trade Organization. But this is not the only means of knowledge privatization. We must add the uncontrolled increase in regulations that lift the WTO's Technical Barriers to Trade, the construction of large infrastructure for scientific research that dissociates knowledge the scientists produce from the means of research, obliging them to sell their talent, and the brain drain, which Fidel Castro denounced as "a looting of brains in Southern countries that dismantles and weakens programs aimed at training human capital."[4]

The system works like this: scientific research is mostly financed

by the large private industry that, given its enormous profits, can assume its cost. This industry possesses large, technological laboratories, to which scientists (many of them from Global South countries) must sell their labor power. The products that emerge from research will be protected by those companies' property patents, guaranteeing a monopoly price that will augment their accumulation even more. In this way, a product of society as a whole (cultural heritage, prior research, training of human capital) is transferred to the private property of the dominant classes. Science, which should work toward the material and spiritual emancipation of humanity, instead facilitates the widening of inequality and an increasing wealth concentration, accompanied by a greater marginalization of people.

In the words of Antonio Negri, "the quality of capitalist accumulation comes to be fundamentally altered in the post-Fordist and post-industrial phase by the emergence of immaterial labor . . . as a central element in the creation of value . . . Exploitation now configures itself as expropriation of the values of cooperation and productive circulation, as capitalist appropriation of the innovative potential of immaterial labor in the social organization of labor."[5] However, as capitalism's knowledge privatization mechanisms become evident, its dysfunctionality also becomes manifest. One can also see how the increasing role of knowledge in the economy and the internalization of science into the value chain exacerbate the capitalist contradiction between social production and private appropriation. Let us return now to the particularities of the connection between science and the economy in Cuba.

THE TRANSITION TO A KNOWLEDGE ECONOMY: CUBA'S URGENT TASK

Transitioning to a knowledge economy is urgent for all countries, but particularly for Cuba, for two reasons. First, because of the size of our country and its demographic changes. There are eleven million Cubans, and our population probably will never exceed twelve

million.[6] Whatever we produce for national consumption (except for some high-demand products) will be in small-scale production at a high cost. For Cuba (like all small countries, including, for instance, Belgium or Holland), the economy of scale significantly corresponds to an export economy. Lacking abundant natural resources, Cuba depends on high added value- and knowledge-content products in terms of costs and prices. Added value and economy of scale generally condition each other (although exceptions exist). The size of our domestic demand does not allow us to internalize the fixed costs of adequate levels of scientific research and sophisticated quality systems, nor the cost reduction associated with the economy of scale. Thus, we risk concluding that it is cheaper to import than produce, and we would not get far down that road.

Let us see it through one of our biotechnology products: recombinant erythropoietin. Today we produce enough of this substance for a population of 300 million, which far exceeds the demand of Cuban patients. It would be unaffordable if we had to produce it for eleven million people. We would have to import this product, produce a lower-quality version, or dispense with it. The problem of the economy of scale is limited to high-tech products. Market globalization forces us to a permanent cost and quality comparison among products. It is possible that food import prices, such as those of eggs and pork, are close to those of national production in national currency if kept at a small scale.

The second pressure leading us to transition to a knowledge economy is demographic. The combination of the increase in life expectancy and the decrease in fertility (related to the Revolution's health and education projects) has made the Cuban population an aging one.[7] In the first decade of the twentieth century, we had a fertility rate of six children per woman (and a life expectancy of 47.6 years). The rate was 4.7 children in the 1960s, but it rapidly dropped below the replacement level in 1978. It has oscillated between 1.54 and 1.64 offspring per woman, which, together with a life expectancy of seventy-seven years and an

infant mortality below six per 1,000 live births, means that, by 2010, 17 percent of the population will be over sixty years of age, and by 2030, that portion will increase to nearly 30 percent (and the mean population age to forty-four years) making Cuba the country with Latin America's and the world's oldest population.[8] This is also true for the developed countries, and a similar demographic transition occurred in Europe. But there, the shift occurred over two hundred years, whereas, in Cuba, it occurred in just thirty years.

We must prepare our economy for this change and do so faster than Europeans. This means, among other things, that the economy's production will be generated by a working population more than forty years of age, that there will be an increasing demand for products and services for older people, and that the working population will have to generate a lot of added value; every person will have to produce for two.

The transition to a knowledge economy is indispensable to preparing a new economy for a new population. Fidel Castro understood this and developed a strategy very early (no one had used the term "knowledge economy" yet) after his 1960 declaration that Cuba's future had to be one of science. He ratified this vision of the relationship between science and the economy (while we faced the difficulties of the Special Period) at the inauguration of Santiago de Cuba's Center for Medical Biophysics in 1993: "Science and the products of science must one day occupy the first place in the national economy. But, starting from scarce resources, especially the energy resources in our country, we have to develop the production of intelligence, and that is our place in the world; there will be no other. All this production [of intelligence] is derived from the efforts we are making in research and research products because we cannot compete with the Japanese, Germans, and everyone else. . . ."

This declaration establishes a historical task. Not assuming it because of limitations in our understanding or by vacillating in the phase of inevitable risks and uncertainty would be an unforgivable

error of our generation of communists. The revolutionary expropriation of land and factories of Yankee monopolies and the Cuban antinational bourgeoisie we carried out in the 1960s would be insufficient if we didn't complement it with another revolutionary struggle against global capitalism's mechanisms to privatize knowledge. This battle is part of the defense of our economic viability and national sovereignty.

In the following three sections, we will see the evidence that we can do this, the reasons why we can do it better under socialism, and last, the challenges we will have to face to do better.

WHAT CUBA LEARNED DURING THESE YEARS

We have provided some data on the performance of the biotechnology sector, which in fifteen years was transformed, starting from a small group of scientific collectives, into a system of more than twenty research-production institutions with more than ten thousand workers that generates hundreds of products for the health system, holds more than nine hundred patents, and has climbed to second place among the tangible assets export sector. An equivalent phenomenon has not occurred in any third-world country, and, as we shall see, positive examples are scarce even in the more industrialized countries.

In analyzing Cuban biotechnology, we do not claim that this sector boasts more capable and committed cadres and workers than others. However, discovering its economic and social mechanisms may be useful. The revolutionary educational work of massive human capital formation in the two preceding decades undeniably enabled the takeoff of Cuban biotechnology from the 1980s on. That resource was expressed in the work of more than two hundred scientific research units. But what triggered the takeoff of Cuban biotechnology was that, based on that human capital, a special organizational scheme of research and production was built. Some of the features of this system are evident; others are not. They include:

1. Whole-cycle organization.
2. Management of the company/budget dualism.
3. Decentralized institutional management.
4. Export orientation.
5. Diversity in negotiation strategies.
6. Integration among institutions (cooperation and not competition).
7. Integration of social tasks.
8. Competitive scientific research.
9. Output based evaluation of scientific research.
10. Learning organization.
11. Attention to workers' motivation.

These features need not be exclusive to biotechnology, not even the high-tech sectors, for they are not technological but characteristics of the established economic organization mode. Each of them will require an essay (someone will write them). I will dedicate at least a paragraph to them.

Whole-cycle organization is employed by the main Cuban biotechnology centers, including CMI. It brings together under the same administration units of scientific research, production, services, and a commercial enterprise, generally with natural circulation attributions, as well as direct exports and imports. The concept of the whole cycle brought scientific research, production, and commercial realization together by enormously reducing the barriers among these activities (in the 1970s) when they were carried out by different organizations. Researchers learned to assess the productive and commercial implications of the new products they investigated from the outset of each project. Producers learned to get involved in the design of escalating processes as soon as a product began to show signs of efficacy. Merchants learned to assemble market penetration strategies by combining current products with those coming after and valorizing accumulated knowledge during transactions. Directors learned to assume and sow within the collective a sense of responsibility regarding

the efficiency of the whole cycle (from the financing of research to the revenue obtained through commercialization) and not about the efficiency of just a fragment of the cycle.

This integrated organization also entailed administrative and economic complexities by combining activities managed under an entrepreneurial scheme (production and sales) with activities managed through a budgeted scheme (scientific research, health programs). As we understand the essential characteristics of our organizations better, the task is to find the inner initiator of that contradiction.

The budgeted scheme (applied to a hospital or school) is not useful: it lacks the necessary dynamics to operate productively and commercially and separates scientific research from its economic applications. The entrepreneurial scheme (applied to other economic sectors) does not work well here either: it does not stimulate or protect intangible asset long-term investment or the boldness to undertake high-risk/high-return projects, nor does it facilitate the integration of centers and social programs. From practical experience (and not from theory), our own organizational and financial schemes must emerge, for these are entities of a new type whose strength is in integrating (and not juxtaposing) activities managed very differently in other sectors. That entities of a new kind have emerged should not surprise us. The direct integration of science into the economy's value chain is historically recent, and every time there have been technological revolutions, they have not been limited to technology. Rather, they also have entailed fundamental changes in organizing production. Hence, the Industrial Revolution in the nineteenth century, based on steam and steel, also "invented" the industrial factory, and the second transition, based on electricity and oil, demanded novel organizational arrangements that led to scientific management as we know it today. In the twenty-first century, the massive use of informatics in industry and the internalization of scientific research in companies also will require new social technologies for organizing work. Their features are just emerging, and we still

lack a mature organizational theory. This organizational progress through trial and error is a risk we must embrace (and even stimulate) because it is the price of being at the forefront and advancing through uncharted territory.

At scientific poles, there are no two identical experiences. Their institutions emerged and have been maintained through decentralized economic management, each with bank accounts and direct-exporting commercial organization. This has allowed the system to have a great adaptive capacity in the face of changing external situations. Decentralizing management has not meant a lack of supervision or accountability vis-à-vis the results, nor distancing from central strategies because of narrow entrepreneurial interests. Management decentralization has meant a quick decision and reaction capacity, the capacity to explore alternatives, and an increased sense of responsibility regarding results.

Another feature common to almost all of our organizations of this kind is their export-oriented character. It is based on the acknowledgment of the reality that a high-tech economy demands the internalizing of scientific research in companies, as well as fixed-cost quality systems, that can only be subsumed under large productive and commercial operations, which are not possible with the domestic demand of a country of eleven million inhabitants. In our context, there is a link between high technology and export capacity, except for a few high-consumption tiers.

Export management has also taught us (through success and error) valuable lessons. The process is incipient, and attempting a systematization of such experiences seems impossible. We can just mention some of its characteristics. One is flexibility: there is not a single negotiation scheme, but rather various, because export management is guided by opportunities. In some countries, the effort has been focused on the sale of known products, whereas in others (those in the industrialized North), negotiations have taken place on products still undergoing clinical research.

We have entered competitive markets in some countries and even participated in tenders. In others, we have entered under the

protection of agreements between governments. Some negotiations have entailed the construction of mixed enterprises abroad (not in Cuba), and others, simple contracts of commercial representation. There has been factory construction abroad (India, China, Iran), although manufacturing rights remain in Cuba in most cases.

Despite this diversity, there are regularities. What has been common to this commercial strategy? First, Cuba's interests prevail over entrepreneurial ones. This entails the establishment of a consult and coordination apparatus. We need flexibility to take advantage of opportunities, integration, and supervision quickly. We have learned they are compatible.

Another regularity is that negotiations are implemented by our commercial companies, not at the centers; that Cuban tangible properties are not part of any negotiation; that mixed enterprises are established abroad, not in Cuba; that negotiations are specific to country and product (or groups of countries and products) and not universal; and that Cuban institutions retain, except in scarce exceptions, manufacturing rights. Each feature would require a specific analysis, but that is not the aim of this chapter.

The most general and important lesson from the commercial experience is that we can manage the combination and apparent contradiction between export management guided by market mechanisms and pay attention to national demand and social programs not guided by market mechanisms or competition among our institutions. This allows us to take advantage of the informational component of market mechanisms (as every negotiation sheds light on the possibilities of our products in comparison with others), and simultaneously avoid the corrupting and distorting effects that competitive, entrepreneurial strategies may have within our country. The geographic zone (today constituted by Cuba) in which distribution is guided more by social principles rather than mercantile ones could slowly expand through the Bolivarian Alliance for the Peoples of Our America (ALBA), as already started to occur with some of our products. At some point

(not yet reached), the commercial penetration within the rich countries in the North will make them partly pay the cost of our distribution, at a differential price, in the social programs in the Global South. Thus we will start expropriating the expropriators.

This integration in Cuba is not limited to a sector's institutions but also includes social programs, mainly health. The perinatal diagnostic programs of the Immunoassay Center, the care programs for the disabled at the Neuroscience Center, the participation of the Finlay Institute and the Center for Genetic Engineering and Biotechnology (CIGB) in the successful Cuban immunization program, and the participation of the CMI and CIGB in the National Cancer Program, are some of the examples. These actions were undertaken with a sense of duty to our people's health. They are not clients but the socialist owners of our institutions. Yet, in the context of a conceptual analysis like the present one, we can reinterpret the actions as an expression of the new kind of institution demanded by the knowledge economy.

For the economic organization of an industrial society (the classical factory or corporation), the most important relations are those occurring within the organization: its internal structure and functional procedures headed to producing tangible goods (products) to be realized in the market and generating the money that allows for the enlarged reproduction of capital. But the knowledge economy's research-production organizations base their success on the creativity and knowledge they accumulate. Given that the latter is the most important factor of production, the aim is to build an enlarged reproduction of the knowledge cycle, for which external collaboration networks and the organization activities outside of it are as important as the internal ones.

This sort of social mediation, which is necessary for economic success, may become a tremendous advantage for socialism, as we shall see. The foundation of competitive advantage vis-à-vis knowledge also implies that scientific research must exhibit a cutting-edge character worldwide. Global competitiveness is needed to subsume high technology within economic organizations, and

scientific research must operate as a function of it and not as a function of incremental and localized improvements.

In the case of Cuba, it cannot be forgotten that any analysis of our economy encounters the reality of the imperialist blockade, which works as another barrier to our development (in addition to the economic barriers that rich countries have erected against the development of all countries in the Global South). The blockade is an element of dissuasion or risk in almost all of our negotiations. We can puncture it only with important innovations and not with small improvements of products that may have some relevance later. The meningitis B vaccine (unique among its kind) and the nimotuzumab antibody for treating cancer exemplify how cutting-edge research punctures barriers. This is a subject where we still have a lot to learn.

At the same time, scientific research must make space for creativity and has to be evaluated on its output (new products, patents, impacts on health) and not only on its inputs (amount of scientists, funding). Here also lies a contradiction we have to deal with. We must ensure that the search for cutting-edge innovations doesn't generate unfinishable projects. We must also ensure that the pressure to release new products doesn't introduce bias that favors imitative projects or the implementation of insignificant improvements. This balance cannot be assessed on a project-to-project basis because it is a feature of the general projects' portfolio. Again, the integration of scientific activity and production and commercialization is what creates a favorable space to get close to that equilibrium.

Last, in our discussion of the economic-organizational features needed for the knowledge economy, we must emphasize motivation and learning. High-tech sectors (note that there is not a dichotomy but rather a continuous gradient of knowledge's weight in the economy) are characterized by the fact that the capital plus labor combination does not suffice concerning productivity. There is a third component, knowledge: that which is possessed, that which is assimilated, and that which is generated. Thus,

organizations must actively occupy themselves in accumulating knowledge and its enlarged reproduction. Besides, this is not only about increasing people's knowledge (although that is the first step) but also generating organizational knowledge, that is, a growing set of experiences, ideas, procedures, and attitudes embedded in the relationships between people and their ways of working. Productive organizations can no longer be built around a product or a technology because both will change at ever higher speeds. They must be built around the continuous capacity to create and assimilate knowledge for new products and technologies.

The assimilation, circulation, debate, and knowledge production must be organized, stimulated, and assessed with the same dedication as producing goods and services. In addition, knowledge must be produced, assimilated, and circulated through interactional networks that are not only internal to an organization but mainly external. This is another reason productivity in this kind of organization depends so much on its connection to society.

A final reflection on this topic may perhaps be the most important one: the chief asset in the organization of the knowledge economy is creativity, which is directly linked to motivation. Dozens of books have been written on the topic of motivation at work. It is not possible to attempt an approach to this issue here. However, as a basis for the discussion on socialism's levers below, let us mention that motivation is closely associated with the people's perception of the continuous expansion of their knowledge and creative capacities, for which technical knowledge is not enough. The organization of learning is not only one of continuous training. It requires, first and foremost, collective construction and a holistic vision of the organization's missions, its future directions, and its role in the major tasks of social construction. Every worker must clearly see their contribution to the big tasks. We need to cultivate shared values and a sense of participation. This is not a theoretical concept but has important practical implications in how we implement communication and the circulation of information, including information on strategies vis-à-vis workers. The

working environment in these organizations is and must be heavily politicized.

Returning to the analysis of Cuban biotechnology institutions as economic organizations, we can see the kind of organization that Cuban practical experience gradually built in this sector: whole-cycle institutions of research-production-commercialization, with a decentralized and specific management system (not the classical entrepreneurial scheme nor that of a budgeted unit) with an export-oriented character via diverse schemes, which in Cuba is combined with the integration of institutions and health programs. This organization utilizes as bargaining levers the novelty of its scientific research and protects continuous learning as its most cherished asset, as well as the workers' motivation and sense of social and political participation. This is the kind of organization that has worked in practice. These features are not exclusive to biotechnology or to any particular technology. This experience can and should be replicated in other sectors as we consciously and in a directed way transit to the knowledge economy we need.

THE CLASH OF CAPITALISM WITH THE KNOWLEDGE ECONOMY: WHAT WE LEARNED AT THE NEGOTIATIONS

Fifteen years of constant negotiations with more than two hundred companies in dozens of countries have compelled us to study the global biotechnology business environment, allowing us to assess strengths and weaknesses of high-tech capitalist companies and begin to outline our opportunities. This is what I will describe in this section. Contrary to popular belief, the most general conclusions are that biotechnology is not working well in industrialized countries; that their current strengths are based on accumulated advantages from prior stages of industrial capitalism; that their current weaknesses arise from the incompatibility of capitalist property and the market and the knowledge economy, and that there lie the advantages of socialism.

Let us review the data. The world's biotechnology sector is

composed of some five thousand companies. About two thousand are in the United States, where more than 70 percent of biotechnology product sales are realized. The number of companies has increased, total sales have grown, today exceeding $50,000 annually, and there are undeniable successes, such as Amgen and Genentech, which have been heavily publicized. On closer inspection, however, the data show that the sector's aggregate profitability has stayed close to zero since 1975, that 93 percent of the sector's sales are made by just fifteen companies (just two account for 53 percent of sales), and that most companies have never generated a product and operate on a negative cash flow.[9]

The appearance of really novel medicines, the products of research, has decreased over years. Companies keep operating with money from three sources: venture capital, the sale of shares on the stock market, and contracts with big pharmaceutical companies. In all three cases, the financial survival of biotechnological companies comes from a money exchange whose source is profits from other economic sectors. These profits are based on the well-known mechanisms of global capitalism: control of raw materials, unequal exchange, control of the world's financial system, and endless extraction of natural resources and surplus value from the third world. It is an economic order based on the violence of primary capital accumulation, which is also sustained by violence (actual or threatened).

That mass of resources, a product of predatory capitalism, is available to finance new companies, high research expenses, and high regulatory standards (which become new barriers to the development of others). It frequently creates the illusion of a productive biotechnological industry based in solid science and managerial systems. Its real strength, however, lies in the use of past labor that was accumulated through spurious mechanisms. Its weakness lies in its limitations in creating new value in the new conditions of the knowledge economy. And these limitations are not scientific-technical; they are structural problems rooted in the capitalist property regime. Let us see why.

When knowledge is transformed into the economy's main source of value, capitalism has no choice but to guarantee the continuity of surplus-value appropriation. Hence the tremendous pressures for the universal application of patents that began at the GATT negotiations in the 1980s, with the embarrassing absurdity of trying to impose commercial sanctions on South Africa for the crime of producing patented drugs against AIDS.[10]

We can attack the intellectual property system because it is immoral, but it also is dysfunctional. Science always creates knowledge from past knowledge and the technological and cultural heritage that belongs to all. No one invents something from nothing. But now, when a researcher undertakes a project, it is most likely that much of the necessary knowledge and technology is someone's property, and thus its use goes through negotiations and economic arrangements. The system thus generates enormous transaction costs that create friction in the economy. This phenomenon is relatively new. In 1980, the United States Congress passed laws to stimulate the appropriation of scientific results through patents; among them, the Bayh-Dole Act (named for its sponsors, the Congress members Birch Bayh and Robert Dole), which allowed universities and small businesses to patent federal government-funded research results and then sell them to the pharmaceutical industry.

To a great extent, knowledge is generated by recombining pieces of different knowledge, which depends on its circulation velocity. The attempt to turn knowledge into private property has fostered research confidentiality and interfered with the free circulation of ideas and scientific findings. This has turned the relations among scientists, which were cooperative relationships for centuries, into competitive relations guided by market laws. A second component of capitalism's failure in the knowledge economy is market pressure for short-term results. This discourages long-term research through which really innovative results should emerge. We thus see the research portfolios of the global pharmaceutical industry focus on small improvements of existing drugs (short-term

and low-risk research), especially those to treat chronic diseases (which a patient must buy for years), and to the detriment of projects seeking in-depth solutions to the diseases that today are the main cause of premature death in the world.

The U.S. Food and Drug Administration (FDA) approved 415 new drugs between 1998 and 2002. Of these, 68 percent were variations of preexisting drugs. Only 14 percent were considered by the FDA as drugs that could produce significant progress.[11] Those drugs that produce marginal improvements are then turned into a sales success by the colossal media machinery, in which the pharmaceutical industry invests more than twice what it invests in research. This is what the market's so-called invisible hand does.

A third component of the failure of market mechanisms in the knowledge economy depends on the extent that knowledge becomes the chief constituent in the value chain; workers' creativity becomes the most important asset in a company. Creativity is an intangible asset that is impossible to appropriate or measure. It is a social process that heavily depends on cultural interactions in and outside an organization. It also depends on workers' motivation beyond economics. Creativity and the commodification of knowledge are directly and irremediably in conflict. Thus, under capitalism, the increasing connection between science and the economy exacerbates the fundamental contradiction between the social character of production (including knowledge production) and the private character of appropriation.

As we have seen in the experience of our external negotiations, companies are pressured by the market to attain short-term profit, oriented to obtaining money in the speculative economy rather than the real one, limited by intellectual property in their knowledge circulation potential,, conflictive rather than cooperative in relationships with other companies, detached from social projects, and pretty much incapable of cultivating consistency and creativity in their workers through mechanisms other than the high wages that they may pay. These structural problems are sometimes not visible, overshadowed by the mass of financial resources companies can

manage and the economic advantage and accumulated infrastructure of the countries where they are based. But they do exist, and as the role of knowledge in the economy increases, the problems of the market economy will grow. Although we are not yet able to generate a theoretical conceptualization, the experience of Cuban biotechnology already has utilized the levers of socialism in:

- The massive investment capacity of the state in the creation of human capital
- The integration among institutions that are not fragmented by competition
- The tight link with social programs (mainly health-related), a source of social legitimacy and knowledge
- The protection that state property provides in negotiations with the external capitalist environment
- The absence of a consumer society that could shift the biotechnology sector from addressing real social necessities
- The link of exports with governmental agreements and solidarity programs in those cases where this is possible
- The capacity to innovate n the structure and management of institutions—whole-cycle organization with decentralized management
- The possibility of long-term protection, taking care of the stability of institutions, investment in human capital, and scientific research in the face of ups and downs in the economic realization of products
- The possibility to implement an intellectual property strategy for our external negotiations without eroding inter-institutional cooperation or our domestic social function
- The national environment of security and social cohesion
- Workers' political and social motivation

THE RISKS WE SHOULD NOT UNDERESTIMATE

We are on the right path, but that path is not without risks. The

task is to face them with the levers of socialism (and not with the "dull instruments of capitalism," as Che Guevara warned). The risks come from outside and inside in a complex mixture, and we will not wear ourselves out trying to classify them.

The main risk is time. The price of oil (which we lack) is on the rise. This is the case with the foodstuffs we import. Globalization of the world economy makes it likely that the domestic demand of small countries has ever less capacity to be a motive force of the economy, and we will increasingly have to complete the economic cycle of our productive apparatus in the external market, which is equivalent to the need of competing in terms of quality and costs at a world scale. Also, in an accelerated fashion, our aging population demands more goods and services and requires a high added-value productive apparatus. The comparative velocity of these processes is very hard to calculate, but the global picture indicates that building a knowledge economy to defend our sovereignty and our socialism is today's task, not tomorrow's. Perversely, neoliberal globalization is bifurcating the world, with rich countries using their accumulated economic advantages in a positive feedback loop to enlarge these advantages and erect new development barriers in poor countries. The socioeconomic development innovations that are possible today may be non-viable tomorrow.

The second risk lies in the damage that the Special Period left. The economic crisis we suffered in the 1990s because of the disappearance of the European socialist bloc, combined with the intensification of the imperialist economic war against Cuba, damaged all aspects of national life. Cubans emerged victorious from the challenge, and our enemies failed in their attempt to destroy the Revolution and socialism. But the wounds from that battle are still there, and overlooking them isn't helpful. We have yet to thoroughly assess the harm to the scientific sector, but the main impacts are easy to see. The Revolution's enormous investment in human capital has been preserved, and Cuba qualifies, along with Brazil, among the countries with the highest scientific potential in Latin America.[12]

It also is true that in the 1990s, university attendance dropped (it is now increasing), investment in science contracted (it has not recovered yet), equipment infrastructure became obsolete in most institutions, especially in universities (and we have not been able to modernize them), and the average age of researchers increased, just to cite some phenomena. Except for biotechnological and medical-pharmaceutical products, as well as the incipient exportation of software, the amount of high value-added products in the structure of our exports is still very small; and even in the sectors where it is larger, it is concentrated in a few destination countries.

The third risk is the damage caused by the brain drain. This plunder mainly affects the countries in the Global South. In the last forty years, more than 1.2 million professionals from Latin America and the Caribbean have emigrated to the United States, Canada, and the United Kingdom.[13] But even the rich European countries are not exempt from the drain of talent that emigrates to the United States. Half of the Europeans who complete their studies in the United States remain there, working longer. This figure reaches 70 percent for professionals from the United Kingdom.[14] Rich countries, in turn, react by creating mechanisms that promote the immigration of professionals and scientists from the Global South.

The increased emigration of qualified personnel to rich Northern countries may create an irreversible dichotomy. Three centuries ago, the Industrial Revolution divided the world in two, between countries that had undergone industrialization and those that became raw material exporters. A new bifurcation between the countries transitioning to the knowledge economy and those that remain exporters of qualified personnel may be developing.

In Cuba, we have successfully faced this challenge. The portion of Cuban scientists who emigrate, relative to the study missions we send abroad, does not exceed 10 percent, while the rates in other Global South countries exceed 50 percent. The brain drain has occurred in the context of imperialism's economic war against Cuba and the particular pressure experienced by our scientists

when they travel. We have not fallen into the trap of reducing our scientific collaboration programs with other countries and our cadre formation abroad, which would have been a suicidal strategy and a gift to our enemies. For Cuba, the successful struggle against the brain drain has expressed the strength of our ideology and culture.

However, this is a long battle, and the pressure on highly qualified professionals, especially scientists, to migrate North will increase. To the same extent that the assimilation and generation of knowledge in production and service companies become the main determinant of competitiveness, as is already occurring in several sectors of the economy and will increasingly occur in other sectors, the promotion of professional and scientific emigration will be more and more a policy of companies and states wherein the power of the world economy lies.

A fourth risk in constructing a knowledge economy is in the practice of centralized business management and the extensive economic growth model, which we inherited from our ties with the European socialist bloc, and especially the USSR, in the 1970s and 1980s. The Soviet model of centralized economic management is not an attribute of socialism but rather of the level of development of the productive forces that existed in the world when "real socialism" began to be built in the first half of the twentieth century. For that stage of development of the productive forces, the model worked and worked very well. It allowed the USSR to transform from a backward and feudal semi-feudal country into one of the world's leading economic and technological powers, to emerge victorious from the Great Patriotic War (which also entailed an enormous productive effort), and to rebuild the country and carry the weight of the construction of the socialist bloc. In the words of Emil Sader, that historical experience has been ". . . the most generous construction created by humanity to this day."[15]

That economic system worked, and for several indicators in the 1950s, it worked better than the U.S. system. But this was the epoch of large-scale industry and massive, standardized production

in enormous factories based on enormous consumption of raw materials and fuels. Soviet socialism created an economic management system appropriate for the existing productive forces. But productive forces changed in the 1970s. There was a shift to the specialization of production, swift technological changes, market fragmentation, and competition for product differentiation, increasingly based on the rapid and flexible introduction of scientific progress within production. Soviet leader Yuri Andropov said in 1983 that ". . . the forms and management methods have lagged behind the demands posed by the current level of technical-material, social, and spiritual development of Soviet society."[16]

In addition to the conflation of socialist property and rigid and bureaucratic economic management methods, social property was rejected in favor of militarizing the economy. And thus began the catastrophe. In the words of José Luis Rodríguez, "…instead of pursuing new forms of socialist economic management that overcame bureaucratic planning methods, voluntarism, and dogmatism; effectively promoting mass participation in economic management, and enhancing development based on scientific-technical progress, they [the USSR] tried to perfect the instruments used for that purpose by capitalism. . . ."[17]

It is not the aim of this work (nor is it the author's field) to analyze the economic factors that led to the dissolution of the USSR. For our purposes, suffice it to say that the economic management methods adopted there did not adapt well to the increasing connections between science and economy that began in the 1970s. Many of these Soviet methods were transplanted into the Cuban economy and remain in some areas.

The task of designing and implementing a decentralized and flexible economic management system that is capable of dynamically taking advantage of the opportunities created by the increasing connection between science and the economy without rejecting social ownership over the means of production and the socialist distribution of the products of the economy, is still pending. A large part of our future depends on its success. This relates

to the eternal polemic on the balance between centralization and decentralization in our business management.

Much economic literature centers on this topic. Our country has cycled through stages of more or less centralization, and the controversy around this issue still exists.[18] Despite the multiple aspects and complexities, which do not allow simplistic approaches or absolute generalizations, what does seem evident is that there are advantages and disadvantages to each approach. Centralization allows the state to rationally use available resources and provide greater long-term protection, but it also lessens companies' efficiency and adaptation capacity. In the long run, it reduces the new resources that are generated.

Conversely, self-management and self-financing can nourish a more efficacious company motivated by microeconomics that reacts more flexibly to changing problems and opportunities, but at the cost of short-term strategies, business interests, and the diversion of resources from the strategic interests of the country, which was Che Guevara's critique of financial self-management.[19] We must find an equilibrium, and the correct balance can change at any historical moment and in each economic sector.

In the context of the knowledge economy, we must emphasize that the appropriate balance between centralization and decentralization depends partly on the technological content and each sector's dynamics. High-tech industries demand more decentralized management. Given their particular dynamics, they suffer more from the corrosive effect of centralization, as they depend more on basal initiatives, exploring opportunities via trial and error, niche markets, and the diversity of strategies among organizations. The negative effects of centralized management schemes in high-tech sectors have nothing to do with material stimulation but rather the length of the information tie between economic opportunities and a company's reaction. On the other hand, labor power's average technical and cultural level within these sectors (and in our country, the political level as well) allows them to assimilate a larger decentralization around decision-making and

resource management, with a relatively lower risk of deviating from national objectives or short-term opportunism.

The idea is that the balance is different for each sector, and it is impossible to think of management and economic control mechanisms that are equally applied to, for instance, the software industry and cattle raising. In fact, referring more to experience than theory, the two main ventures linking science and the economy we have developed in Cuba, the biotechnological industry and the University of Informatic Sciences (UCI), were born with a high degree of economic management autonomy. As these sectors grow, new controls will be required, but we must find and implement those that practical life demands, and not more. Establishing a regulatory context appropriate to accelerate the connections between science and the economy without ever giving up socialist ownership is one of the challenges that lie ahead.

Last, there is a fifth risk that is particular to the context of the Cuban Revolution, which had to build its socioeconomic project under the enormous pressure of the most powerful empire that has ever existed, which has opted to make us renounce our ideals through starvation. This fifth risk consists in that the urgent need for economic results encourages a short-term outlook within these sectors, which could be expressed, in reduced scientific research investment, tardy decisions about productive investments, a commercial strategy exclusively focused on immediate and low-risk operations, or paying insufficient attention to the permanent quantitative and qualitative growth of our human capital. With the best intentions, we could fall into this trap and begin to resemble the pharmaceutical industry in underdeveloped capitalism.

Cuban biotechnology is far ahead of most underdeveloped countries in transforming scientific results into productive and economic processes. This is recognized by friends and foes alike. From the right perspective, these successes can be taken as evidence that we can go further. But from another, erroneous perspective, they could encourage complacency, the feeling that we have already done enough and there is no reason to embrace the

uncertainty of new, audacious initiatives. Fidel Castro's close attention to these sectors protected them from those risks, although they remain.We must be vigilant about them.

TODAY'S TASKS

The experience of Cuban biotechnology could remain a singular scientific phenomenon, attributable to the happy coincidence of a group of committed scientists with certain favorable external conjunctures and serve as a showcase of our resistance capacity and our culture. That would be fair but insufficient. Or it could alert us to the gradual transformation of our economy based on its connection to science, an opportunity we can and must seize on a larger scale, identifying and using the levers of socialism.

The October Revolution developed in the economic context of the Industrial Revolution. Half a century later, the Cuban Revolution emerged in the epoch of the scientific-technical revolution. This historical difference thus poses a set of different challenges and opportunities for which there is no recipe. From the 1960s on, the world economy hastened a transition to the intensive and direct use of scientific research. This change transforms not only technologies and products but also the forms of organizing economic and scientific activities and the links between them. In this, we have to be as creative as in science itself. The task is not only scientific development but mainly connecting science and the economy. The survival of a small country in an economy of global competitiveness and the accelerated demographic transition of our population imply that this is an urgent task for Cuba. But at the same time, the results of incipient experiences, such as biotechnology (and socialism), make this task urgent and achievable. This reminds us of Marx's observation that humanity "thus inevitably sets itself only such tasks as it can solve."[20]

The possibilities that socialism puts in our hands for an accelerated transition to a knowledge economy are increasingly evident because of our experience and as capitalism's contradictions become more

apparent in its attempt to turn everyone's labor into private property. Socialism also is the conscious direction of social processes. The connection of Cuban science to the economy can rapidly influence two basic developmental indicators: production's added value and the structure of human resources in the productive apparatus. But this process cannot be left to spontaneity. It demands conscious intervention, management, and political work, and we must face and overcome large, external distorting pressures. We have to consolidate and proliferate a new type of economic organization that combines scientific, productive, and commercial activities, is connected abroad to a diverse economic network of export operations and increasing profits, and toward the interior to a network of health programs with a socialist, and indeed communist, approach.

We must design innovative economic management systems for this emergent productive apparatus that combine management decentralization—essential to efficiency and rapid responses—and the fierce defense of social property over the means of production and the socialist distribution of social products. This last issue will probably entail the design of new, superior institutional and strategically-oriented structures and improving the organizations' internal structures.

We have to find the mechanisms to recover a higher level of investment in scientific research, not only that realized in the whole-cycle centers but also in universities, the health system, and other institutions that foster creativity and the immediate social connection of results. And, most important, because it gives cohesion and meaning to all of the above, the Communist Party's work in scientific centers and research-production organizations must reach higher levels to develop people's social consciousness in the new economy. Only social consciousness can nourish motivation and creativity, coming from the profound understanding by scientists, technicians, and all workers, that their daily efforts are part of a broader political struggle that will enable humanity to finally leave its social prehistory behind.

CHAPTER 7

Knowledge, Society, and National Sovereignty in the Twenty-First Century

"National independence is not a banner, an anthem, or a shield; independence is not a matter of symbols; independence depends on technology, depends on science."

— Fidel Castro, 1991

WHAT IS THE INTENT OF THIS WORK?

"In today's fast and interconnected world, the sovereignty of nations can no longer rely solely on a self-sustaining capacity for survival but increasingly requires a capacity to spread meaningful messages (material, technological, and cultural) for the rest of humanity."[1] I wrote those words in 1994, the worst year of the Special Period. This book, written fifteen years later, seeks to expand and ground that idea. Elsewhere I have attempted to approach the connection between science and the economy. My aim now is to link both (science and the economy) to the larger issue of the defense of our national sovereignty and our viability as a nation in the face of the complicated twenty-first century.[2]

Before getting started, a crucial warning for the reader. This chapter has a bias: my point of view. We all view reality from

experience. In this case, it has been the development of the Cuban biotechnology industry, which, through its particularities, allows a view of more general phenomena. They include complex negotiations with more than twenty countries with different socioeconomic contexts. The central controversy in all these negotiations has been and will be the valorization of knowledge. Some interesting generalizations can stem from it, but readers must be warned that not all can be equally valid in all contexts. Therefore, readers will have to draw their own conclusions.

This work is not about biotechnology (although it stems from this experience). The threats to our national sovereignty, derived from the accelerated globalization of the economy, will have to be identified and faced by every conscious Cuban, especially every cadre, in their tasks. It is also essential to start from the principle that the defense of our national sovereignty is non-negotiable. Some intellectuals have come to wonder whether national sovereignty (especially of small nations) is viable in the twenty-first century. Some express these doubts cynically, others sadly and with resignation. In either case, these lines are not intended for them. They can stop reading now.

People need solid points of reference to construct an effective task. Doubting everything is the best recipe for paralyzing any action, and it only serves the interests of those who benefit from maintaining the *status quo*. For us, the sovereignty of the Cuban nation is one of those unquestionable principles.

THE THREATENED NATION-STATE

The nation-state, as we know it today, is a nineteenth-century phenomenon.[3] Its emergence was not spontaneous but an elaborate effort whose motive was economic. As the economy became more technological, it started requiring ever larger collectivities for production, specialization, and exchange, demanding more complex forms of public administration. There was a lot of diversity in the historical formation of each country, and in each of them,

the territorial, economic, ethnic, linguistic, religious, and cultural components have had different weights vis-à-vis their construction of the nation-state and its cohesion. But there are also common phenomena. One of them is the link between nation-state formation and education. The increasing complexity of the economy and the consequent interaction among people made oral communication insufficient and progressively demanded a given level of basic education. In many countries, the nation-state's emergence was directly tied to the organization of primary production.

Another common phenomenon is related to defense. The nineteenth century was characterized by accelerated capital accumulation, which in principle, had no limits. This destabilized traditional international politics and demanded a broader organization that would protect nations against the economic expansion of other nations. The basic model of nationalism was the territorial state that emerged from the French Revolution. This model also contained the political concept of the social contract, according to which citizens had duties to the state but the state assumed the moral duty and responsibility of guaranteeing the citizens' well-being. Thus, political life since the nineteenth century has essentially been one of power relations within and among nation-states, and the immediate aim of many revolutions has been the conquest of state power to impose new bases for the social contract.

Colonization by the European nation-states allowed them to subjugate, in what we now call the third world, nationalities (well-defined in ethnic, linguistic, and cultural terms) that had not yet matured as nation-states and obtain from their exploitation the necessary resources and secure the captive markets they required for capital accumulation. Between 1770 and 1800, developed countries' per capita economic product was relatively similar to developing countries. In 1880, it was twice as large; in 1913, it was three times as large; and in 1950, it was five times as large.[4] Except for the United States, colonies did not undergo industrialization and were trapped in the role they were assigned, which was

to complement the core countries' economies and not compete against them.

Decolonization, initiated in the nineteenth century by the independence revolutions in the Americas and completed by the decolonization of Africa in the twentieth century, gave rise to new nation-states that aspired to undertake their own social development and economic paths. These nation-states were the primary actors (at least in theory) in the struggle for development. Such development has not occurred, and regardless of the indicators with which it is measured, the reality is that the rift between rich and poor countries has grown and is still increasing.[5] Today, half of humanity (three billion people) lives below the poverty line, and 25 percent of children do not consume sufficient protein and calories.[6]

Nation-states of the developing world were denied the possibility of fulfilling their historical mission, and today they are also being threatened with disappearance. The increasing neoliberal globalization of the economy puts the very existence of those states at risk. Reducing transportation and communication costs and developing technologies that allow large-scale production have increased the movement of products, services, and capital, generating globalization analogous to the formation of national economies more than one-hundred years ago.[7]

Globalization opened a new era of conquest, but now the conquistadors are multinational corporations, especially those of the United States. These corporations and globalization's international management organisms (the International Monetary Fund, World Bank, and the World Trade Organization) increasingly limit the ability of sovereign states to make their own economic decisions. The IMF has become a quotidian actor in the economic life of underdeveloped countries. In some cases, the agreements between governments and the IMF have established laws the countries must pass to fulfill the requirements to receive loans.[8] These requirements have coerced public policies toward the dogmas of neoliberal globalization (privatizations, reductions in social

expenditure, free capital flows), which have consistently favored the interests of the rich countries.

From our point of view, what is taking place is a transfer of decision-making power from the sovereign state to the international economic institutions that express the interests of the large corporations of the dominant countries. The contradiction is that nation-states are, at least in theory, politically and morally responsible to their citizens, while international economic organizations are not. Thus, what this process really signifies is a separation between the power over the people's lives and the responsibility vis-à-vis those same people: a dismantling of the social contract and a profoundly reactionary step that hearkens back to the eighteenth-century political order that existed before the French Revolution. Power and responsibility had not been separated (at least in political theory) since the Middle Ages. That is where neoliberal globalization can lead us.

CUBA: THE NATION THAT WE ARE

Let us see how the processes operate in Cuba.

If there is something no one doubts, neither Cubans, their friends, or their enemies, is the solidness of Cuban national consciousness. It emerged in the nineteenth century from decades of war in a population of a little more than one million inhabitants that was occupied by thousands of enemy soldiers. It rendered annexation to the United States impossible, even when that country's army occupied our national territory and annexed others. It forced the repeal of the Platt Amendment; it resisted, over the first half of the twentieth century, decades of U.S. ideological and cultural pressure; it resisted, in the second half of that century, fifty years of economic war, military hostility, and ideological subversion from the most powerful imperialist power that has ever existed; and it has more recently faced the challenge derived from the disappearance of the European socialist bloc, which shook our economy and confounded the ideologies

on the left throughout the world. What are we Cubans, then, in all of this?

Let us start by saying what we are not. We are not a nationality with a single ethnic or religious origin. We are a "crucible," as the essayist Fernando Ortiz Fernández put it. We are not defined by a language either: ours is spoken in many other countries. However, we do have a culture that makes us proud. It is not a closed culture but one that shares roots with many other cultures from several continents. Our economy also always has been open. What, then, identifies us and binds us together? We are essentially a nationality with ethical roots, united around a special sensitivity to social justice. The starting point of Cuban culture is ethics as the guiding principle of politics.[9] We are Cubans not because we are a special ethnic group or because we are identified by a language or a religion. We are Cubans because we share a set of moral values and a project of human coexistence.

The origins of this special connection between ethics and national consciousness can be found in the works of Cuban thinkers since the eighteenth century and their magisterial synthesis in the thought of José Martí. We Cubans know by heart Martí's sayings, such as "I want the first law of our Republic to be the Cubans' cult of the full dignity of man [*sic*]," or "It would be better if that flag did not unfold from its mast, if it were not to equally protect all heads!"[10]

But Martí, who gave his life for the independence of Cuba, did not conceive independence as an end in itself, but rather as a starting point, as a capacity for sovereign action, to construct, with it, the revolution that had to be carried out in our Republic with all and for the good of all. Thus emerged the Cuban nation, tied to and defined by the conquest of "all justice." Let us recall that the first action, on the first day of revolutionary power in arms in 1868 was the abolition of slavery. (In the United States, the independence from England let slavery stand for several decades, and its abolition required another war.)

The Revolution of 1959 reinforced in the Cubans that fusion

of nationality and social justice, expressed in the thought of Fidel Castro and the activity of these last fifty years: total literacy and schooling, free education and healthcare for all, full-coverage social security, full employment, the elimination of racial discrimination, women's equality and development, universalization of culture and university instruction, and housing. And the list could go on. And it should, because today's Cubans, 70 percent of whom were born after the triumph of the Revolution, are so used to these achievements that sometimes we forget how advanced they are, and how much they contradict the dominant ideology of today's rampant capitalism. As Martí foresaw, we needed total national sovereignty to build and defend all of that.

In fifty years, Cuba implemented an advanced social justice and development program, probably one of the most advanced in the world. We have an infant mortality rate below six per 1,000 live births, a life expectancy at birth of 77.9 years, a 99.8 percent literacy rate among adults, universal schooling among children, an unemployment rate below 2 percent, and the world's highest per capita number of medical doctors and teachers.[11]

The Cuban experience has demonstrated that all this can be achieved in a small country with scarce resources. None of it would have been possible had we followed the economic policies dictated to the world from Washington. National sovereignty has allowed us to build our own alternative. The essence of sovereignty is precisely the right to choose. National sovereignty is the safeguard of our social project, of our own concepts of justice and human coexistence, as they have emerged from our history.

THE DYNAMICS OF THE ECONOMY AND SOCIAL JUSTICE

As impressive as the social achievements of the Cuban Revolution may be, the most remarkable thing (and the most subversive in today's world) isn't those achievements themselves but that they were attained before Cuba reached industrialization and growth proportional to the output of the national economy.

Mainstream economic thought holds that underdeveloped countries must achieve economic growth that generates a resource surplus to finance social development. The Cuban Revolution proposed an inverse logic, based on the immediate access to social and distributive justice, that generated high levels of equality, education, health, and social security, which would serve as the foundation for economic growth. And this was accomplished. Practically any social indicator (infant mortality, life expectancy, schooling) mapped cross-nationally as a function of GDP per capita shows an almost linear correlation, yielding high values for social indicators in rich countries and low ones among poor nations. In this mapping, the "Cuban dot" deviates from the correlation line and illustrates the possibility of attaining high social indicators in a low-resource economy.

A potentiality that many capitalist economists try to dismiss as nonexistent was undoubtedly developed in Cuba. This constitutes the so-called subversive character of the Cuban Revolution, which has not only denounced capitalism's unfair economic order but has constructed an alternative. It is also the reason behind the imperialist blockade and the permanent hostility to the Cuban Revolution. It has little to do with the recovery of nationalized properties (many of which now have little value) and a lot to do with attempts to deny socialism's enormous potentialities for social and economic development.

The main factor that supported the constructive efforts of the last five decades, even amid enormous material difficulties, was the ethical attachment of most Cubans to the ideal of "conquering all justice" propagated by José Martí and magnified by Fidel Castro. This ideal constitutes the chief bond of Cuban national consciousness. This also was the main lesson we learned from the Special Period. When the dissolution of the USSR and the European socialist bloc cost us 35 percent of our GDP and 80 percent of foreign trade, it reduced fuel availability to a fifth of its value and significantly affected access to food. Despite this, the nation sustained its cohesion and social project, resisted the crisis, and began

to recover. One of the most beautiful lessons in our history became evident: the collective Cuban soul is much more attached to justice than to riches. Thus the defense of the homeland and the defense of socialism were fused in the national consciousness. Neither is possible by itself.

That defense of the homeland and socialism has occurred, as we know very well, amid the colossal external pressure and hostility of North American imperialism to the very idea of Cuban national sovereignty. This hostility has endured for more than a century. In 1823, John Quincy Adams stated in a letter that "…it is scarcely possible to resist the conviction that the annexation of Cuba to our federal republic will be indispensable."[12]

Cuban economic strategies cannot be analyzed without taking this reality into account. Any internal economic or political process (and this in every Latin American country, but especially in Cuba) has immediate consequences concerning that external dynamic of hostility/defense. In addition, the distorting effect of the North American economy on other countries' economies has increased as a consequence of neoliberal globalization. In fact, the United States has been globalization's great winner. But that same globalization made capital rent in the United States highly dependent on income flows from abroad. In 2000, the income from other countries (in the form of investment remuneration, profits obtained in U.S. subsidiaries abroad, among others) amounted to $381 billion, exceeding profits generated by the internal economy.[13] Thus, foreigners finance the dominant class's consumption orgy in the United States. This situation is exacerbated by the devastating effects of the economic-financial crisis.

THE NEW CHALLENGES

The work of the Revolution initially could be financed with the economic resources expropriated from the bourgeoisie. With the nationalization laws passed between 1960 and 1963, 95 percent of industry, 98 percent of construction, 70 percent of agriculture,

and 100 percent of wholesale trade became state property.[14] Our economic production, which before the Revolution would be appropriated as profits for U.S. firms that owned our assets or would finance the luxuries of the Cuban bourgeoisie, passed into the hands of the people and was placed at the service of our social and economic development. The fair exchange terms for our products that we later achieved with the USSR and the socialist bloc enhanced the value of those resources, which were invested in everything we could build.

However, what passed into the hands of the people was an underdeveloped, non-industrialized, and non-diversified economy, with primary production having relatively low added value. With those resources, we developed during the last five decades. But in that same period, the world changed, and it did so in the sense of the continuous erosion in the value of the products of underdeveloped countries.

- Exchange terms tended to deteriorate vis-à-vis basic products, which means that primary producing countries (excluding oil countries) have to produce much more to acquire fewer industrial products.[15]
- Knowledge has become the chief resource for the most advanced economies, which entails an increasing proportion of high-tech products and services in constant replacement, wherein knowledge is the main component in their cost and price, the main limiting resource.[16]
- Globalization caused international trade to grow faster than the world economy. This allowed companies in industrialized countries to envision producing for the world, developing large-scale production and reducing costs, which created a crisis for several products vis-à-vis the strategy of "import substitution," one of the chief theses of the developmentalist efforts in the 1960s.
- The rich countries (especially the United States) concentrated more power and successfully imposed neoliberal globalization based on privatization, deregulation, reduced social spending,

> a reduced (or eliminated) state role in the economy, free circulation of capital, and increasing financial speculation. Thus, globalization and the knowledge economy, which could have been (and perhaps still can be) positive forces for constructing equality and reducing poverty, instead became a function of the increasing concentration of wealth, with the consequent marginalization of people. As the Spanish academic and journalist Ignacio Ramonet remarked, never have the owners of the world been so few.

The intrinsic mechanisms of these macroeconomic processes and their infamous global, economic, environmental, and human consequences have been analyzed in innumerable documents and international events, and I do not have enough space here, or the intention, to review them. I will limit myself to emphasizing their impact on the subject that occupies us: national sovereignty.

The mandates of the Washington Consensus and the three big managers of neoliberal globalization (the IMF, WB, and WTO) constrain countries' exercise of national sovereignty. As the Nobel Prize economist Joseph Stiglitz put it, "Globalization, as it has been advocated, often seems to replace the old dictatorships of national elites with new dictatorships of international finance. Countries are effectively told that if they don't follow certain conditions, the capital markets or the IMF will refuse to lend them money. They are basically forced to give up part of their sovereignty…."[17]

This is not a tragedy that we Cubans have had to endure. With the people in power, the levers of the economy in the hands of the socialist state, and our history of having successfully resisted the imperialist economic blockade, even after the loss of our allies in the socialist bloc, Cuba is the freest country in the world today. But at the same time, we Cuban communists have to reject naivete about the future and be up for the challenges, for the world's macroeconomic processes could also erode our national sovereignty if we do not defend ourselves with firmness and intelligence.

In the economy of the twenty-first century, neither the national

control of natural resources will be a sufficient (although it will remain a necessary) lever for development, nor will the satisfaction of the national demand for products and services be, for small countries like Cuba, sufficient for growth. We will increasingly have to obtain our resources from exports, especially from exports of goods and services of high added value. These products must be competitive worldwide (both in quality and cost) in a market where neoliberal capitalism still imposes the rules.

In 1993, while inaugurating the Center for Medical Biophysics in Santiago de Cuba, Fidel Castro said, "Science and the products of science must one day occupy the first place in the national economy. Starting from scarce resources, especially the energy resources in our country, we have to develop the production of intelligence, and that is our place in the world, there will be no other." His reflection points to a historical task. We have to create a type of economic organization capable of fulfilling it. It will have to combine scientific research, new product development, efficient production, and export management, penetrating markets that will be increasingly protected by regulatory and intellectual property barriers. We already have some embryos of this kind of organization.

We must protect, without concessions, the social character of property, for this is sovereignty, the guarantee of socialism. But the new economic organization will have to operate with decentralized management mechanisms. This is because in high-tech industries charged with producing innovative goods and services and exploiting short-term external market opportunities, centralized operational and financial management, although it may produce short-term cost reductions, increases opportunity costs by eliminating flexibility and speed from an organization, hampering its ability to react to opportunities.

We have to continue protecting equality, guaranteeing education, health, employment, and security for all; and relatively narrow wage differentials, even with the principle of "to each according to their labor," since equity has been and continues to

be the historical root of our society's cohesion, which is ultimately the main defense of our sovereignty.

CULTURE AS A BROKER

At this point, a reader might think that the preceding section proposes tasks that are easier said than done since they encompass internal contradictions. And this is true. The previous section discussed decentralized economic, financial, and export management, and this opens the door to resource overuse and eventually to corruption. We learned this during the Special Period. We also spoke of protecting equity and differential incomes, and we know that one of the problems from the Special Period we still face is the relative loss of the role of wages as a stimulus. Any manager from the Communist Party, of the government, or of our companies has faced these two contradictions in their fields in one way or another. And at this point, readers may have connected them to their own experiences. Let us examine them more closely.

A given "equation" links management decentralization to the possibility of resource splurge and corruption. But the "coefficient" that links both variables is not fixed but depends on culture, including technology and political culture. Economic operations of high technological content directed by managers with high technical and political training allow greater room for decentralization and vice versa. In the knowledge economy, these sectors are the least susceptible to procedural standardization and, thus, the most sensitive to the inhibitory effect of excessive regulations and centralization.

Another equation relates work motivation and productivity to wage differentials (the stimulus) a worker receives from these results. Again, the coefficient linking both things is not constant but rather culture-dependent. The more creative and technically complex the working activity, the less sensitive workers' motivation to wage incentives, and vice versa. This does not mean the effect is null or will disappear soon. But it is relatively less important.

Scientific discoveries, technological solutions, first-rate medical services, and pedagogical contributions will not be consequences of wage incentives, even though society will later repay them in one way or another. In the knowledge economy, productivity depends more on creativity and motivation than standardization and discipline (although both remain important). Seen from another lens, obtaining important productivity increases at work with small wage differentials must be possible. This is not theoretical; it has been our experience for years.

This way, culture (general, technical, and political) becomes the brokering factor that permits us to seize opportunities derived from decentralized economic management without having to pay the price for disorder and splurge and should allow us to maintain a high degree of equity in what citizens receive from society, without having to pay the price (or paying a minimum one) for demotivation and being unproductive. These balances need not be homogeneous because of these relationships' dependency vis-à-vis the technical and cultural levels. The optimal point of each relationship is different across economic sectors. The defense of our national sovereignty also follows from the success we may achieve in displacing these delicate balances toward the equitable, inclusive, cultivated, and technically productive socialist society we want to construct.

YES, WE CAN

If globalization tends to construct an interconnected world economy, where economic viability depends on the quantity and quality of its connections, and if this global economy is designed and administered by international entities that serve the interests of rich countries and are neither politically nor morally committed to the development of others, can we successfully defend our national sovereignty and our advanced social project? Yes, we can. And there are four powerful reasons.

The first reason is that we have human capital: healthy people

with an elevated educational level, hundreds of thousands of professionals, and dozens of thousands of scientists. Our education system continues to expand that human capital, which has lately been the foundation of our economic growth based on high-value services, and it has also linked science with production and exports, as in the biotechnology industry and more recently in software production.

Second, as we delve into the knowledge economy, the capitalist economic system expresses its contradictions and limitations more openly. Knowledge becomes the main factor of production, which is considerably harder to privatize than capital goods. The attempt to privatize knowledge generates friction in the system (transaction costs) and intensifies the system's chief contradiction between the social character of production (especially of knowledge) and the private character of appropriation. The current controversies around the decrease in scientific productivity in the large North American and European pharmaceutical industries illustrate this situation. These concepts have been discussed in preceding chapters; I will not elaborate further here.

Suffice it to say that the correlation between the size of the rich countries' economies and their scientific production does not necessarily mean that the latter is feeding their economic growth. In several cases, it is exactly the other way around. There is an accumulated advantage amassed by the rich countries for centuries, the product of colonization and unequal exchange, allowing them to invest more in scientific research. But that correlation does not imply causation, and the same entry barriers (increasing technical regulations, intellectual property, among others) that they have been erecting to privatize knowledge based on competition increasingly complicate the connection between science and the economy.

The international negotiations of the Cuban biotechnology industry and the revenue obtained also have allowed us to observe the complex balance of risks and opportunities in connecting a knowledge-based, emerging productive sector to the world

economy. Hundreds of negotiation actions have involved more than fifty countries, and each is different. Yet some common features have emerged:

- The strength of Cuban human capital, which is usually absent in the companies with whom we negotiate, even in the rich countries, and which cannot be bought with money.
- The importance of having closed-cycle, research-production institutions and retaining the added value of production, resisting the pressure of negotiating patents that have not yet been turned into products.
- The linkages among our institutions and between them and the Cuban health system, which guarantee the scale of productive operations and knowledge production about product usage.
- The fragility of intellectual property barriers, which are built to dissuade competition.
- The increasing use of regulatory barriers as a protectionist instrument impedes the development of high-technology productive sectors in the Global South countries. These barriers even erode the scientific productivity of industrialized countries.
- The solidity we gain by inserting ourselves into the world as a country without making concessions that damage our national interests, even if they may be advantageous for a given company.

The third reason Cuba can defend its national sovereignty and social project is that neoliberalism, despite its initial ideological success, is rapidly declining. Although in the 1990s, the confusion created by the dissolution of the USSR allowed capitalist ideologues to impose the fundamentalist doctrine of "all power to the market" in more radical terms than Adam Smith enunciated in 1776.[18] Today, after the failures of the neoliberal doctrine in Asia, Russia, Mexico, Argentina, and other countries, fewer and fewer people believe in it. Popular discontent is expressed in multiple

protests against globalization and its administrative agents and in increased organized political behavior, as in the position of the Global South countries at the Doha Round Negotiations,[19] the failure of the Free Trade Area of the Americas,[20] and in governmental economic programs that reject neoliberal dogma and begin to construct economic spaces (such as ALBA) where the state guides the economy toward social objectives.[21]

The fourth reason, directly linked to the central subject of this article, lies in the ethical roots of the Cuban national consciousness, indissolubly linked to the ideal of social justice. That legacy of our history links the defense of national sovereignty to a societal project whose essential components are justice and solidarity. José Martí did not limit this project to the well-being of Cubans but connected it to the contributions Cubans can and must make to the larger work of humankind. A few weeks before his death, Marti wrote:

> In the work of the world, each one must put oneself to what is closest to them, not because what is theirs, because it is theirs, is superior to what is not, and finer or more virtuous, but because the influence of human beings is best and most naturally exercised in that which they know and where it is immediately painful or pleasurable; and this sharing of human labor, and nothing more, constitutes the true and unassailable concept of homeland. . . .[22]

This beautiful statement contains two important components of Martí's homeland concept: its connection to knowledge, shared ideas and values, and the acknowledgment of a duty of contributing to humankind that must materialize while we build on those ideas and values. These shared ideas and values allowed us to resist decades of attempted U.S. cultural colonization, the blockade, and the fifteen years of the Special Period. They are expressed daily, in work, in Communist Party tasks, in social programs, and in the actions of our complex social fabric. Every militant could identify

several examples in their practice of how ideals of justice and solidarity prevail in Cuban thinking and practice.

In the years of the Special Period (and still today), there were instances where apathy, skepticism, egoism, and even corruption prevailed. We talk about this every day, and we will continue to, but without ever forgetting that many more Cubans held on to their commitment, trust, and firmness during the harshest circumstances. They are the fourth reason we say, "yes, we can."

THE CHALLENGE OF RELATIVE VELOCITIES

In a 1967 speech, Martin Luther King said, "We are now faced with the fact that tomorrow is today. We are confronted with the fierce urgency of now. In this unfolding conundrum of life and history there is such a thing as being too late."[23] Social thinkers try to identify ongoing processes and predict where current tendencies might lead us, but it is far more difficult to predict the speed of these processes. And everything depends on those relative velocities. Regarding knowledge society and national sovereignty, there are at least seven important processes that influence each other:

1. Globalization of the economy that links economic performance with the capacity to connect to the global economy with high value-added products and services, which erodes the national sovereignty of small countries.
2. Concentration of wealth and economic (and military) power in fewer countries, especially the United States, which empowers them to manage economic globalization to favor their interests, to construct barriers (protectionism, subsidies, technical regulations, intellectual property) to the development of the Global South countries and strip them of skilled personnel through selective migration policies (brain drain).
3. Global economic crisis stemming from uncontrolled financial speculation, food and energy prices, and increasing environmental degradation.

4. Transition to a knowledge economy, which takes a relative weight off the accumulated ownership of capital goods and creates a window of opportunity for development based on human capital.
5. Decline of market fundamentalism (neoliberal ideology), which creates conditions for the emergence of regional integration alternatives and for the collective defense of the Global South's interests within international economic organizations.
6. Construction of integrative economic alternatives among developing countries, such as ALBA, PETROCARIBE, MERCOSUR, and CARICOM, among others, which, at different rhythms, could transition from the sphere of trade agreements to the higher realm of productive integration.
7. Cuban economic recovery following the Special Period and based on the human capital developed by the Revolution.

At what speed will these seven processes occur? We do not know, but it largely depends on us.

In a world where the concentration of wealth and power and the imposition of capitalism's irresponsible politics exceed awareness about the need for change and to construct alternatives, the world may be heading toward a point of no return in its economic, food, energy, and environmental crises, as well as in the irreversible deepening of the North-South division. The message we Cuban revolutionaries draw from this analysis is that we can influence these processes and contribute to the "world's equilibrium," a task proposed by José Martí more than a century ago. To attain that end, the first step is the defense of national sovereignty because it is only on that basis that we can construct our social and economic alternatives. Then we must demonstrate that we can build a knowledge economy capable of successfully inserting itself in the global trade flows of high-technology goods and services. We must also demonstrate that we can continuously expand our domestic human capital and enhance equity and social justice.

The historical functions of the sovereign nation-state have not

been superseded in the twenty-first century, as the imperialist ideologues of limited sovereignty like to say. It is the other way around: the functions of the sovereign nation-state are needed today more than ever because, in the conjuncture of the disappearance of the European socialist bloc, followed by the rapid exhaustion of the neoliberal capitalist organization model, the exploration of new alternatives is urgently required. These alternatives—locally diverse and globally connected—must combine knowledge-based economic development, sustainability, and social justice.

We Cuban communists will make our contribution, which many people worldwide are expecting and observing. Our model is made by hand, day by day, across all spaces of our society. Each of us has tasks in this work, which entails the construction of efficient connections between our scientific centers and our companies, increased labor productivity, speed and efficacy vis-à-vis investments, the potentiality of the municipal university seats to influence socioeconomic development across territories, increased and diversified exports and their content in high value-added goods and services, increased food production, energy conservation, and the continuous improvement of our education system.

In ideological work, the main task is to reinforce in every Cuban the conscious understanding of the indissoluble link between sovereignty and socialism and that our daily activities are part of a larger historical task. We are getting closer, step by step, to the knowledge economy, through every new technology we introduce, with every increase in labor productivity, with every new high-value-added product or service, with every increase in the value of our exports, with every result in our scientific investigations. We also are approaching Martí's ideal of "whole justice" daily through every social program we successfully implement, with every improvement in our wage policy, and with every development of our health, education, and cultural institutions. Thus we construct not only the spiritual and material well-being of our people but also the defense of national sovereignty. We must inspire confidence that we can do it, but we

also have to understand, realistically, that we do not have all the time in the world to progress slowly.

We are moving forward, and many countries are undergoing important changes. But there are also powerful regressive forces worldwide that influence the possibilities of moving forward. It is the relative dynamics of these forces that will define the future. That is what we mean in the Communist Party when we talk of working with a sense of urgency: understanding where we want to go and what to do and then doing it well and quickly.

CHAPTER 8

The Functions of Science in the Cuban Economic Model

In April 2011, the sixth Congress of the Communist Party of Cuba approved the "guidelines for the economic and social policy of the Party and the Revolution" to ". . . update the Cuban economic model to guarantee the continuity and irreversibility of socialism."[1] We Cuban revolutionaries are putting all the enthusiasm, effort, and intelligence we can mobilize into successfully implementing these guidelines.[2] For this, we need to extract knowledge from every useful experience but mainly from our own in constructing the socialist Cuban society, allowing us to see the world from our perspectives. The rise of the biotechnology industry in Cuba in the 1980s, as this industry was emerging in the more technologically developed countries, and its growth during the three ensuing decades until it became an important export sector of the Cuban economy is one of those experiences.[3]

This is the appropriate and necessary moment to analyze this experience in relation to the Cuban economic model and especially to identify the functions of science in this economic model.

The experience of the Scientific Pole—as our advanced biotechnology and pharmaceutical industry is usually known—and our

medical equipment exhibit specificities within the context of the Cuban economy, which are important to underscore as the starting points of this analysis. Beginning in January 1992 with the inauguration by Commander-in-Chief Fidel Castro of a small laboratory of thirty scientists in charge of producing Interferon, Cuba's biotechnology industry grew rapidly through new institutions and products until becoming what it is today. It is a set of twenty-seven entities that employ more than ten thousand workers operating factories in Cuba and abroad, contributing 141 products to Cuba's basic list of essential medicines [cuadro básico], and realizing exports to more than fifty countries, worth several hundred million USD. This productive, export, and infrastructure development resisted the Special Period, when our economy, facing the disappearance of the European socialist bloc and the strengthening of the North American blockade, suffered a significant GDP and market contraction, and other sectors of our economy had to substantively reduce their activities.

Scientific Pole exports have grown by more than 30 percent per year in the last decade. They are non-traditional products (many of them holding Cuban intellectual property rights) exported to diverse destinations with different regulatory environments, which has also required non-traditional negotiation schemes. This operation did not rely on foreign investment or external credit. It was a state investment, which was recovered and enlarged in a surprisingly brief term. The negotiations did not in any way compromise state ownership of the assets. A similar process has not occurred in any other Latin American country. It has not happened in Cuba in other economic sectors. The successful Cuban experiences of tourism development and mining during the same period also were based on different investment, management, and negotiation schemes.

Of course, there are scientific determinants and particularities of the biopharmaceutical sector and the Cuban biotechnological industry, but the essence of those experiences is not found there. They do have something to tell us about the direct connection

between science and economy and the management of the socialist state enterprise. If we can discover these messages, the experience of the Scientific Pole will cease to be particular and will foreshadow what the high-tech socialist state enterprise could be, built upon the fertile basis of human capital and the social cohesion created by the Revolution.

INTUITIONS: WHAT DID WE LEARN FROM THIS EXPERIENCE?

Here I use the term "intuitions" to underscore that a rigorous analysis of the micro- and macroeconomic determinants of the evolution of Cuba's biotechnology industry must be carried out by other colleagues specializing in economics. Here, we will limit ourselves to exposing the regularities and general ideas that we non-economists who participated in developing these institutions can draw from experience. There are seven of them.

1. There is a global contextual change for the development of our economy, given by the relationship between technologies and globalization. Understandably, when we talk of a contextual change for the Cuban economy, the first thing that comes to mind is the disappearance of the European socialist bloc, with which, three decades ago, we conducted more than 80 percent of our foreign trade. We also had long-term economic integration agreements with the European socialist countries. Yet, for our purposes, it is essential to identify another external process of contextual change that would have created tensions for the Cuban economy even if the socialist bloc still existed. The preeminence of the difficulties caused by the dissolution of the socialist bloc and the U.S. blockade must not prevent us from seeing this other underlying process. This other change depends on the accelerated technological development during the second half of the twentieth century and the globalization of the economy, made possible by that same technological development and on their effect on smaller economies like ours. We are transitioning to an economy in which industrial products are being rapidly replaced by improved ones, and

productive technologies permit enormous scales of production and great reductions in unit prices.

These two phenomena reinforce each other through a positive feedback loop: the profitability of the modern production process is only possible with enormous scales of production, which is only possible if there are large markets for the products. In turn, these large productive operations make it possible to subsume the high fixed costs of scientific research for developing new products and the quality standards that maintain competitiveness. This is an objective tendency of the development of the productive forces, and it will continue. The direct consequence for small countries like ours is the diminished power of domestic demand as the engine of industrial development.

The "developmentalist" theories in force in the Latin American economic thought of the 1960s proposed national industrialization, including the assimilation of technologies to substitute imports.[4] In Cuba, during the revolutionary period before 1986, external income was based on sugar and nickel. The resources to finance the development of the economic infrastructure to satisfy the domestic demand came from them. This was the correct strategy then, which allowed us to get here. However, it is no longer viable in this new context. Our experience with cutting-edge medicines taught us we cannot produce them only for domestic demand. This is the limitation of the import substitution concept: at some point, the argument that it is cheaper to import than to produce always emerges. We need large export operations for technological development to occur. Many of the medicines and vaccines of the Scientific Pole are produced today at a scale twenty times larger than the domestic demand. This ratio is larger than that between export and domestic consumption for sugarcane.

We now believe that the same argument could be applied to the production of computers, telecommunications equipment, complex building materials, and other industries. It is more evident for high-tech products, but the relationship between technological development and exports will progressively permeate all productive

sectors, except for food production. Contextual changes are always accompanied by new opportunities but also by new dangers. We will have to learn how to build the Cuban socialist economy amid a new global context in which our planning cannot control (except for the small fraction of domestic demand) the market size, prices, technical standards, or the changing dynamics of this context.

2. Economic development concerns high-tech industries in this new context. Our country has achieved a positive balance in foreign trade, an essential accomplishment following the dissolution of the European socialist bloc and the continuation of the U.S. economic war against Cuba. This achievement cannot be minimized in any analysis of the subject. It is also true that this balance is reached at the expense of the export of services. Our foreign balance in trade in goods remains negative. This situation could and must improve with the import substitution of foodstuffs (whose prices will not stop increasing), but in a country with scarce natural resources and a stable and highly qualified population with an ever-larger mean age, the positive external balance must be attained with high-value-added products. As stated by guideline 78, "Diversify the structure of exports of goods and services, preferably those with higher-value-added and technological content."[5]

Our people's material and spiritual standard of living and the social victories of the Revolution must be defended economically through high-value-added production. Where will these products come from? Again, the experience of the Scientific Pole may have something to say about this. For more than twenty years, the organizations of the Scientific Pole have negotiated with private, public, small, and large institutions in more than fifty countries across all continents. A thorough analysis of that experience is yet to be made and lies beyond this chapter's scope. But a first approximation indicates that it is very difficult to create export spaces for products with a low innovation content and in competition against several producers worldwide.

Modern technology for industry's traditional products (textiles, simple electronics, and others) allows for production scales that

surpass the world's solvent demand. However, there is not, nor will there be, overproduction for innovative products and those that do not yet exist. It is thus essential to create innovative products, which does not always mean unique products, but rather products that are not easy to create, either for their technology, quality standards, or the qualifications of the labor-power required to make them. Hence, two mechanisms create export spaces: an agreement between governments to guarantee broad access to their populations and avoid abusive prices for innovative products when they come from industrialized countries and our products' uniqueness and highly innovative content, which enables them to be marketed even in the absence of agreements between governments.

Both mechanisms are related and balance each other. The stronger one is, the weaker the other and vice versa. But both require high knowledge content and science in product development and production. This is not achieved by simply importing technologies. The experience of Cuban vaccines, erythropoietin, heberprot-p,[6] the SUMA systems, cutting-edge generic drugs, monoclonal antibodies, and many other products confirms this point.[7] Either we make innovative products or we will not have-high value-added exports to finance the continuity of our economic and social development.

3. This task is not limited to scientific development. The main issue is the connection between science and the economy. Scientific research is the human activity structured and conducted to obtain new and generalizable knowledge. For centuries, knowledge was essentially confined within universities. By the early twentieth century, in some countries, it started being directly financed by the state but still within a budgeted sector. In the 1950s, companies began to internalize knowledge. In some countries, its role in development and competitiveness became evident.

The importance of scientific research and knowledge management for economic development has been extensively discussed, and there is abundant international and Cuban literature on the topic. I will not elaborate here on the existence of this influence of

science on the economy but rather on the mechanisms whereby it is produced. The idea that simply "sowing science" (training scientists, creating institutions, increasing the scientific budget) will somehow translate into economic development is naïve and corresponds to another moment and countries. Of course, sowing science is a necessary condition. What's new is that it is no longer a sufficient condition, as it was in the twentieth century.

When today's industrialized and technologically advanced nations began their development more than 150 years ago, they had, in many productive sectors, a technological level that was inferior to what we have today in the Global South. In 1880, the per capita rent in developed countries was just twice that of the Global South nations, and they were nonetheless the technological vanguard. There was no other "first world" to look at. No multinational corporations in other countries accrued innovations and flooded the markets. There was no "brain drain." National scientific development and innovations were directly channeled to the national industry. This is not the current world.

It is well-known that there is a wide and increasing distance between industrialized and underdeveloped nations concerning scientific production. But what is most important is that the distance is greater for using science. Global South nations, home to 81.7 percent of the world's population, produce 32.4 percent of scientific publications but hold only 4.5 percent of the patents. Of the estimated 59 million immigrants living in developed nations, twenty million have attained higher education.[8] In the domestic economies of industrialized nations, over the last fifty years, scientific activity has been internalized within companies. Today, the amount of scientific investment financed by companies amounts to 64 percent in France, 71 percent in the United States and Germany, and 79 percent in Japan.[9] In the Global South, scientific internalization within economic organizations has not occurred, and scientific activity is still predominantly academic and mostly financed by the state. Results are not transferred to national companies, and the disoriented promotion of scientific activities does

not generate socially valuable technologies. This only multiplies irrelevant and hard-to-access information.

In the case of Cuban biotechnology, what explains its industrial development is certainly not a larger investment in scientific research. The GDP percentage that Cuba dedicates to science and technology (0.72 percent) is lower than Latin America's (1.09 percent). Our scientific literature production also is lower. Budgetary financing for Cuban scientific research also suffered the effects of the Special Period. What was built in the Scientific Pole from the 1980s on was a system of direct links between research and production within a self-financing economic cycle.[10]

4. New technologies require a new kind of company. The main product that emerged from the Scientific Pole was not a vaccine or antibodies but a type of economic organization. If we examine Cuba's biotechnology institutions not as scientific centers (although they are) but as economic organizations, we can see the type of organization that practical experience gradually built:

- Whole-cycle institutions of research-production-commercialization.
- Direct export orientation and activity and the direct import of inputs.
- Decentralized management that is neither the classic entrepreneurial system nor the budgeted unit.
- Institutions integrated into a system of mutual research, production, and external negotiations empowerment. (This system is integrated into the social products in Cuba, essentially with those of the health system.) Scientific research integrated as part of fixed costs and strengthened through research conducted in the Cuban institutions that use the products.
- Scientific potential as a bargaining lever, valorizing in its transactions not only the products but also intangible assets.

The productive organization of the knowledge economy cannot be constructed around a product or a technology since both change

at increasing rates. Such an organization must be constructed around a continuous capacity for creating and assimilating knowledge that generates new products and technologies. Hence the need to internalize scientific research within the productive organization. In the historically short span of the Cuban biotechnology industry, many centers have had to change their leading export product several times.

From a historical perspective, this experience emerges as another case of the regularity whereby new technologies rarely insert themselves into preexisting human organizations but instead "invent" their own type of organization. This way, centuries ago, new agricultural technologies invented the farm; the first industrial revolution (based on steam and steel) invented the factory; and the third industrial revolution (based on electricity and oil) led to industrial scientific management as we know it today. In today's world, the increasing integration between science and production begins at the scientific laboratories in industries, but it ends up inventing a new type of productive organization for the knowledge economy, which inserts scientific research into the value chain and utilizes it as an asset in the commercial negotiations to obtain added value.

The emergence of high-tech companies is not exclusive to biotechnology (although in Cuba, it began with it). It can be seen in other sectors, such as electronics, telecommunications, software, new materials, and renewable energies. It will gradually arise in all sectors of production.

5. The high-tech company requires a specific regulatory context Technologies and market opportunities are not the only factors in the emergence and development of companies. They are also supported or inhibited by the regulatory context in which they operate. In all countries, economic regulations are built as a function of certain objectives and prevailing social values (generally different across nations). There are always goals and values behind the regulations. The attention given to the nascent biotechnological institutions that emerged in Cuba from directives of the State

Council and, in many cases, Commander-in-Chief Fidel Castro protected them from the possible inhibitory effect of regulations (even if well-conceived) that served other purposes for other innovations. Let us see why this inhibitory risk is real.

In recent years, Cuba's purchasing power abroad has oscillated around 20 percent of its GDP. Even considering the pitfalls of linear extrapolations from economic indicators, this figure suggests that there is a small portion of our economy (a fifth perhaps) that operates as a function of external demand, while the remainder does so as a function of the domestic one. The productive organizations operating for the external market generally demonstrate greater labor productivity, even when calculating income in currencies equivalent to Cuba's domestic currency at a 1:1 ratio. The difference in productivity would be even greater if we used another exchange rate that better reflected the currency's purchasing power. The organizations that work to satisfy the domestic demand (which are numerically more abundant) have had, as of late, low labor productivity, which the National Assembly has publicly discussed and criticized.

Can we regulate both realms of our national economy in the same way? Obviously not. And when we try to dissect the general objectives of the regulations governing the economy, this dichotomy becomes more evident. The most important task is increasing labor productivity. For those sectors with high productivity, the most important issue is growth in the volume of its economic activity. This growth, even if it were to occur at the expense of smaller reductions in labor productivity, would increase the national mean productivity. For most of the national economy, the growth bottleneck lies in production. Domestic demand is not saturated for most products. But for export sectors, that bottleneck is frequently not production capacity but the penetration of external markets. Savings and unit cost reductions in operations are critically important. In export sectors that are meant to grow, the opportunity cost (the market opportunity we lose if we do nothing) is more important, and the operations that open markets may

make sense even if they increase unit costs (of course, within profitability ranges).

In the sectors that operate as a function of domestic demand, our socialist planning can decide what demand to satisfy, internal prices, and products' technical standards. Demand, prices, and technical standards are not under our control in export sectors, and opportunities and unforeseen problems frequently arise. The conclusion that emerges is that regulations that introduce pressures for the constant increase of productivity (for instance, by linking it to salary raises) and for the continuous reduction of unit costs will undoubtedly be convenient for most of the national economy, but it can be problematic for the emerging high-tech export sectors.

The global trend in high-technology sectors has been and will continue to be an increase in fixed costs of scientific research, new product development, and the evolution of quality standards. We have to accept and face this tendency by subsuming fixed costs into productive and export operations of larger volumes and not by searching for marginal savings in our current processes. This does not mean that savings are not important (it would be far-fetched to say so), but rather that, in the real life of microeconomic (and not macroeconomic) decisions, the aims of savings and growth may be at odds with each other. When this happens, we sometimes must prioritize savings; at other times, growth.

In a budgeted social activity, the priority will always be savings. In a productive activity that satisfies captive, volume, and price demand under state control, savings (and efficiency) also are the priority. However, growth is the priority in a productive activity designed to create external demand. The primary goal of increasing efficiency is not to increase unitary gains but rather to generate a range of prices to augment the penetration of external markets. This reasoning does not imply that high-technology export sectors should not be regulated, but rather that they must be regulated differently and that no economic regulations are universally applicable to all economic sectors and all types

of companies. Regulations always reflect underlying objectives and priorities. They cannot be the same when savings (at a constant activity volume), instead of growth, is the priority. It is not a matter of counterposing productivity and growth but rather of recognizing that there are actions aimed at increasing short-term productivity (frequently focused on the organization of labor) and actions geared toward attaining the sustainability of that productivity in the medium term (which frequently depend on knowledge management and investment). In the high-technology sectors, the medium term arrives very rapidly.

This problem is not new or exclusively Cuban. In other countries where the growth of high-tech sectors has been proposed, there are antecedents of differentiated regulatory contexts for these sectors. In the United States, the emergence in 1971 of a new stock market, NASDAQ, complementary to the New York Stock Exchange and with different regulations. The emergence in 1995 of London's Alternative Investment Market, the Special Economic Zones in China and India, and other similar developments attempted to create regulatory contexts to incentivize the development of technological enterprises based on novel products and risk investment. (They are usually small companies focused on growth.) None of these experiences is identical to another, and none can be copied for Cuba. However, they all have in common the need for regulations to stimulate and protect the growth of these sectors, which does not occur spontaneously in the context of the rules governing the traditional economy.

The more advanced the technology and the newer a company's products, the less predictable its operations and indicators are. The regulatory context must provide a space for exploration, risk, and rapid adaptation for this type of company, a space greater than what is tolerable for more conventional technology companies and the known market.

6. Foreign investment is not the appropriate lever for developing high-technology companies. One of the features that most surprises those who write abroad about Cuban biotechnology is

that it was developed as a state investment without foreign capital. Perhaps it developed because of that. To our knowledge, no country has an innovative biotechnology sector that emerged from foreign industrialized nations' investment.

Even in the so-called emerging countries, neither China, India, nor Brazil has achieved accelerated biotechnology development. The first production facilities of therapeutic monoclonal antibodies in China and India were mixed companies in collaboration with Cuba. Brazil's first recombinant proteins factory also was created in conjunction with Cuba. The "Biotechnological Corridor" attempted by Malaysia's government through the attraction of foreign investment did not materialize. China's strategy of the technological park also has been criticized because multinational corporations investing there transfer their mass manufacturing of certain products but retain in the countries of origin their scientific research, product development, and post-sales assessment, the most important parts of the value chain of the knowledge-intensive industries.[11]

Economic globalization in today's world has been developed by rich countries for their own benefit, and the prevailing international economic relations under neoliberal capitalism have many predator-prey dynamics. The just economic relations we built with the Soviet Union and other socialist countries represented a different model that no longer exists. The economic relations that Cuba and Venezuela are building in the context of ALBA also are a different model, still under construction.

The sources of direct foreign investment of the industrialized capitalist countries operate with the rules of competition for the appropriation of maximum profits. This entails the retention of the essential links of the value chain. The transition to a knowledge-based economy has progressively displaced those essential links from manufacturing to product development and scientific research. These essential links will not be transferred by foreign investment.

The Global North countries that began transitioning to a knowledge economy started from preexisting industrialization

internalized scientific capabilities in their industries and from their financial strength and market control. The history of Cuba's biotechnology industry is exactly the opposite of this. It is a story of building productive capacity from preexisting scientific capacity and human capital. This trajectory retains the sources of value added in Cuba, which would not be the case if we relied on foreign investment (which does not mean we don't selectively use it for certain operations). This (in addition to the U.S. blockade) explains the futility of the approaches of the European pharmaceutical industry to Cuban biotechnology. The experience from multiple negotiations has been an incompatibility between those companies' interests to rent scientific capacity in Cuba or purchase our patents and our demand to tear down their protectionist walls and thus gain access to their markets for Cuba's industry.

7. Combating the monopolies of multinational companies requires regional agreements between governments. Despite the neoliberal discourse around free trade, the historical practice of capitalism in developed nations has been essentially protectionist. The transition to a knowledge economy reinforces this protectionism vis-à-vis high value-added products, a consequence of the direct impact of science. In these sectors of the economy, the dominant countries of world capitalism and their companies have resorted to two main types (non-tariff) of barriers: the intellectual property barrier (patents) and technical barriers. Both work as brakes so the Global South countries do not produce high-tech goods and services.

We have seen the patent barriers weaken in recent years, especially in the pharmaceutical sector. The World Trade Organization demands the worldwide recognition of patents, but it is also the case that many high-selling products are reaching the expiration date of their patents. Even before their expiration, maintaining high drug prices to protect intellectual property can become politically unsustainable, as was demonstrated in the successful challenges by South Africa and Brazil to the patents of AIDS drugs.[12]

At the same time, technical barriers, in the form of regulations

on the attributes that products and processes must have, are growing rapidly. This form of technological protectionism also isn't limited to the barriers to entry developed countries erect for their domestic markets. Rather, the demand for global harmonization of regulations allows them to protect the markets of all the world's countries and preserve them for their own companies. Those of us who have worked in biotechnology see this clearly since these trends are expressed in the pharmaceutical sector in a more visible way than in others. But the attempt of companies in the North to monopolize the world market by erecting technical barriers (disguised as quality standards) to the entry of new producers, especially for high-tech products, is a tendency that has been emerging in other sectors (for example, food production) and will spread to new ones.

The immediate consequence is that developing high value-added industries in Cuba and other countries in the Global South will require regional agreements among governments that create spaces for our producers and foster a regulatory context where the priority is the social impact of the new products. Many large export and technology transfer operations at the Scientific Pole have had this focus, where industrial development transcends the economic interaction between companies to become increasingly linked to political strategies.

THE CHALLENGE IN THE MEDIUM TERM

In current debates, when people in Cuba talk about the economy, the common expression is "economic difficulties." These difficulties are real, and disregarding them would be irresponsible. But it is also true that any serious analysis of the Cuban economy must begin by recognizing that, in the twenty years that preceded the Sixth Congress of the Communist Party (April 16, 2011), our country waged a colossal battle in the economic field, facing the Special Period, and emerged victorious from that battle; with injuries and repercussions, but essentially victorious.

An abrupt loss of more than 80 percent of foreign trade, a more than 30 percent decline in our GDP, an enormous increase in oil prices, and the persistence of an unprecedented external economic aggression were confronted without significant declines in the basic education, health, citizen security, and equity and employment indicators, as was recognized in the "Human Development Index" studies published by the United Nations.[13] Cuba reoriented its foreign trade, rebalanced its internal and external finances, restarted its GDP growth, and, for several indicators, recovered the figures that existed before 1989.

We are now fighting a second battle in the aftermath of the Special Period. This battle demands, as expressed in the guidelines of the Sixth Congress of the Party, "short-term solutions aimed at eliminating the deficit in the balance of payments, which promote the generation of external income and import substitutions, and in turn respond to the problems with the greatest immediate impact on economic efficiency, motivation for work, and the distribution of income…We will correct the distortions of the Special Period, ratifying the principle that in the Cuban socialist society, no one will be left unprotected."[14]

However, we must face two more challenges of a permanent character vis-à-vis our economy: the demographics of the Cuban population and the globalization of the economy and their interaction. In the 1950s, we had a population pyramid with a very wide base, with many young people, not unlike that of 1907 (yet more evidence that dependent capitalism contributed little or nothing to Cuban social development). In the five decades following the triumph of the Revolution in 1959, the age structure of the Cuban population underwent modifications. We now have a pyramid with a narrow base, more than 18 percent of the population is over sixty years old, and this percentage likely will increase to 30 percent by 2030.[15] The birth rate fell below the replacement level, and the number of Cubans reaching the working age are barely able to replace those reaching retirement age.

The problem should be seen as one of the outcomes of the

social achievements of the Revolution. Part of the complex causality underlying this demographic transition is the increase in life expectancy at birth and the reduction in the birth rate that follows the increased educational attainment of women and their social inclusion. A similar transition occurred in Europe and North America in the twentieth century, albeit more slowly and mirroring industrial development. In Cuba, we produced social development ahead of economic development. This is essentially positive, as it reflects the political principle that human rights to health and education must be exercised without delay, distributing whatever we have. This is a problem we should be proud of having. Yet it does not cease to be a problem for which we must find solutions. If we managed to build social development from politics (and not the economy), now we must build economic development from the social development we created. A demographic structure like ours demands a technological, high-value-added economy; no more, no less. It will require a lot of creativity. There are no external models for a challenge of this nature.

And now, the second challenge: we must build such high-value-added productive apparatus in the context of economic globalization, a world economy very different from that in the 1960s when the Revolution developed its first economic development programs. Capitalism has been globalized from its inception, and the insatiable urge to expand markets lies at the heart of colonial wars of conquest four hundred years ago. But the globalization rate and the growth in international trade, far exceeding production growth, have accelerated dramatically in the last fifty years. Our economy (ours and all small countries) will depend more on external economic relations. And we cannot stabilize our external economic balance with traditional products and even less so with non-renewable natural resources, of which we have few. Tourism and medical services function as compensating aspects and factors of economic stability, but they have their growth limits. If our industrial apparatus does not transition rapidly to high value-added products through the cutting-edge capacity for production

that lies on the border between science and technology, we run the risk of deindustrializing, losing industrial jobs, the unrestrained expansion of services, a persistent commercial deficit, and the erosion of human capital.

The ability to establish diversified and symmetrical economic relations with the world is, ultimately, a national sovereignty issue. If we do not rapidly build productive capacity for high-tech products, we will reestablish relations of subordination with the world because Cuba would be supplied with products manufactured externally without us having the ability to develop new knowledge from within. All the scientific potential we have must be involved in this battle. We certainly have these capabilities in Cuba, but we cannot avoid a third challenge: recovery from the damage wrought by the Special Period. The Special Period affected all realms of national life, including science. The percentage of GDP we invested in science and technology in 2001 was 0.98 percent, higher than the Latin American average.[16] In 2007, our investment in science and technology dropped to 0.72 percent [as of this writing, it is below the Latin American average of 1.09 percent]. In 2007, our production rate of scientific articles was 6.67 per 100,000 inhabitants, a figure below the mean (8.20 per 100,000) for Latin America and the Caribbean. In a compilation made for UNESCO by the Canadian Observatory of Science and Technology [*Canadian Observatoire des sciences et des technologies*], 775 scientific publications from Cuba were registered, a figure considerably lower than the 6,197 publications coming from Argentina, the 8,262 from Mexico, and the 26,482 from Brazil.

In 2008, our percentage of internet users was 12.94 percent, lower than Argentina (28.11 percent), Mexico (21.4 percent), and Brazil (37.5 percent). But beyond these figures, the view shared by many is that the economic difficulties of the Special Period drastically affected scientific activity, but the biotechnology sector constitutes one of the exceptions to this phenomenon. In fact, in the chapter on Cuba in the 2010 UNESCO report on science, practically all the examples UNESCO cited when discussing research

results came from the biotechnology sector.[17] It is not a matter of more competent or dedicated scientists working in these institutions than in others. How is it then that in the same period when scientific activity in all fields suffered the impact of the Special Period, it remained productive and grew in the biotechnology sector? The answer must be sought in the direct interaction, whole-cycle model, which was built with a double transfer: the transfer of scientific results to production within the same organization and the transfer of commercial and export resources to the scientific activity.

Finding a viable scheme of scientific research financing in the economic model that we are redesigning, within and without the business system, is one of our biggest challenges in science and the economic model itself. In that vein, guideline number 24 reads: "The research centers based on production and services must be part of the companies or of the superior organizations of business management, whenever possible."[18] This is just one of the components of the strategy.

THE BATTLEFRONTS

The "Economic and Social Policy Guidelines" approved during the VI Congress of the Communist Party of Cuba clearly established that strategies to address economic problems must have two kinds of solutions: short-term, seeking an equilibrium between the balance of payments and an increase in economic efficiency and motivation for work, and sustainable solutions in the longer term. The latter should lead to: "…high food and energy self-sufficiency, as well as the development of new production of goods and services with high added value."[19]

This production of high value-added goods and services has three possible origins: either we import technologies with our limited resources or seek foreign investment (thereby risking new dependency relations), or we extract them from our scientific capability. The first two options could be quick but unsustainable.

The third, derived from our scientific activity, is robust. Countries have always been built from the inside out and not vice versa. But could this route be a quick one?

We must fight this battle on at least four fronts:

1. The high-tech socialist company: This is the first function of science in the economic model: to gestate and give rise to high-tech companies. Regardless of the specific production sector, a high-tech company is a business organization capable of building a complete cycle of research-production-commercialization, which allows it to create novel, high-value-added products that can be periodically substituted for enhanced ones through high and increasing quality standards. These companies generally operate at a low cost per dollar and high labor productivity and employ highly qualified human resources. In large nations, these companies can operate according to domestic demand. In the case of small countries, there is an inescapable link between high technology and exports. This type of company arose in Cuba from biotechnology, though it could have emerged in other sectors.

We need to codify in our laws and regulations this type of organization and its forms of operation and identify which other organizations, in this or other sectors of the economy, could become this type of company. In these companies, the connections between science and the economy go both ways. It is not only the case that scientific results rapidly turn into new products and services but also that the commercial realization (mainly exports) of these products and services becomes a source of financing for scientific research. Both links occur in the context of the same organization without the transaction costs inherent to the academia-company relationships in different establishments.

The emergence of high-tech companies from scientific collectives expresses the maturity of our science and technology system. It is the chief tool whereby the inputs of social investment in science and technology are transformed into economic outputs. These organizations do not conform to the traditional schemes of either the company or the budgeted unit. Rather, they have traits

of both: like any company, they must be profitable and efficient in the short term and grow in their operations, but they must also address the medium term, subsume important research and development expenses for new products, and assume social missions related to the impact of new products. These organizations will require a clear conceptualization within our economic model and a "tailored suit" for their forms of functioning and control.

It will also be essential to carefully design the higher organizations of business management for the high-technology sectors, which should be capable of designing and conducting the strategies, and of evaluating the performance of the base organizations not only according to the annual plans but also in the more complex progress in the areas of development in the medium and long term. They should also be able to handle the uncertainties of external markets and take advantage of the integration that derives from the social ownership of these companies. These new higher organizations of business management will have to be endowed with the capacity to interpret scientific and technological trends in their sector.

2. Innovation throughout the business system: The second function of science in the economic model is to increase the added value of the products and services of the entire productive apparatus. Regardless of our production operations' higher or lower technological level, their added value must grow. We must accept that the classical scheme of spontaneous innovation plus results (entailing moral and material stimulus for the innovator), which worked for decades, is exhausted. We must determine why. The persistent complaint of many scientific leaders that the corporate apparatus does not use the results produced by our science indicates that there are underlying reasons for this. Either the results of whose insufficient introduction we complain are not so "translatable," or the business apparatus lacks incentives to introduce them, or a mixture of both. The image of the individual innovator with a brilliant idea that can be immediately applied is a twentieth-century notion that does not work in the twenty-first century. In

modern companies, innovation is a structured activity within the whole organization, integrated into its essential processes.

Innovation does not always have to stem from a company's scientific discoveries or Cuban scientific institutions. The computing revolution has made available online a lot of low-cost information and technologies. What is essential is that a company can absorb these technologies and scientific discoveries. Innovation must be guided by demand and incentivized by the opportunities identified regarding new products and services that increase profitability. The introduction of innovations frequently goes through investment decisions or at least through an interval between the innovative effort and its economic revenue. These procedures, and the incentives to employ them, must be captured in new company laws and implemented in all sectors of our economy.

3. Universities: A third function of science in the economic model lies in the rapprochement between Cuban society's teaching and productive institutions. Most of the human capital for scientific research, which has, on average, higher academic qualifications, is found at universities and other higher education centers. One of the main damages from the Special Period was the loosening of the links between universities and the economy we built since the 1960s, drawing on the thought of Fidel Castro and Ernesto Guevara. To recover and multiply the role of higher education in the economy, and not only in the formation of cadres, is one of the urgencies of the current moment. This is a two-way interaction: the impact of ideas and results from the university's human potential on the economy and the impact of such interaction on the quality of teaching. The social connectivity of science is not limited to its ties with the productive apparatus but also importantly includes the links between science and education. This is the only way in which scientific potential can self-reproduce. Much has been written about the university-company relationship. It is not my aim, nor do I have the qualifications, to review this literature. Other colleagues in Cuba have produced important reflections on the subject.[20] Here, I will only underscore some intuitions that

emerge from the experience of the biotechnology sector, in this case, regarding its interactions with higher education.

We must avoid two distortions: the copying of intellectual property plus the patent negotiation model, which has guided the university-industry interaction in developed capitalist nations. That model introduces market relations into the use of knowledge, generates new transaction costs, and weakens the commitment of researchers vis-à-vis the impact of their findings on society. Even intellectuals in the countries that follow the model increasingly criticize it as dysfunctional. The second distortion is universities building small factories and commercializing products. Such a mechanical interpretation of the university-industry relationship is not the way either. The link must be built by preserving the specificities of scientific activities in universities and businesses. Scientific research has a larger exploratory content, while business research focuses more on the exploitation and enlargement of results. Scientific research is for projects with a higher risk (and larger potential returns), which need to be financed under a budgetary scheme since their recovery cycle does not fit into the economic logic of business life.

Scientific research operates with a larger number of human resources, including students, and is more interdisciplinary since its impact encompasses the training of cadres. The richness lies precisely in the interaction of different lenses. We do not have frames of reference to study how this is achieved under socialism. The Soviet experience was unsuccessful in mobilizing the academic environment as a function of economic development.[21] The weak links between science and production in the USSR (despite having 25 percent of the world's scientists) were one of the determining stagnation factors that preceded its dissolution. We in Cuba must be very creative in building our own model.

4. Municipal university centers and local development: This fourth function of science in the economic model is the most ambitious. It consists of building a system of knowledge production, structuring, circulation, and absorption in society. This

concept of knowledge management is broader, embracing scientific research as we traditionally know it, but it also encompasses other purposes, such as identifying needs for knowledge and its possible sources, the development of absorptive capacity for science and technology in the business apparatus, the capturing of company-generated tacit knowledge, the construction of local productive chains, and the assimilation of the scientific method as a component of the common knowledge of Cuban society. The extension of the scientific method in our society, as a method of thought and generation and assessment of hypotheses, as well as of the social ability to interpret and assimilate science, may seem like a far-fetched goal. However, it is no more far-fetched than the literacy campaign we successfully carried out in one year (1961).

The first experiences in local development programs based on knowledge management indicate that these objectives are achievable and have enormous potential for the economy, teaching, science, and culture.[22] The connection between science and the economy is not spontaneous; it requires conscious direction, strategy, mediation, and catalytic strategies. The 123 Municipal University Centers (MUCs) established in 2004 can be very powerful for these purposes. The MUCs can be leading actors in local economic development, capturing and distributing knowledge, becoming the main educational and scientific institution at the municipality level, and building connections between local institutions and those in other territories, including national scientific centers.

THE LEVERS OF SOCIALISM

In today's interconnected world, scientific development cannot be mistaken for the volume of scientific activity, that is, the number of researchers, scientific centers, scientific publications, and the percentage of GDP invested in science. Scientific development is the combination of the volume of scientific activity and the connections of such activity, that is, the interactions with the economy,

education, and other sectors of society. This connection between science and production, on which the added value of our production and the export performance of our economy depends, has the state socialist company as its main actor. The state socialist company is the group through which social property over the fundamental means of production and the distribution of the social product according to work is expressed.

The Cuban economic model must include mechanisms to produce this connection between science and the economy. This is precisely what guideline 132 urges us to do: "Perfecting the organizing, judicial, and institutional conditions to establish the types of economic organization that guarantee the combination of scientific research, technological innovation, the rapid and efficacious development of new products and services, their efficient production through pertinent quality standards, and their domestic and exporting marketing management."[23]

The experience of biotechnology in Cuba provides us with an experiment in this process. In fact, the centers of the Scientific Pole have been operating as high-tech socialist companies, where the social ownership and decentralized management that should increasingly characterize our productive apparatus have worked pretty well. Biotechnology also has demonstrated socialism's advantages regarding the link between science and production and the transition to a knowledge economy. Private property and the market economy are obstacles to connecting science and the economy.

The limitation we have seen in developing biotechnology in other Latin American countries lies in the private character of the productive apparatus (and its subordination to the capitalist nations), which decouples it from the social process of creating scientific knowledge. Both sectors, science and production, are independently linked to scientific and productive entities abroad, but they do not interact with each other. Only socialism can break this vicious circle of dependency. In Cuba, this isn't theoretical; we have evidence that it can be attained. But, in addition to the

evidence, we now have the responsibility to capture these experiences and delineate in our economic model and all of its diverse settings the processes whereby scientific development will progressively assume a direct role as the motive force of economic development, and not only be a distant consequence of it.

With its massive project of developing human capital, social cohesion, and values, the Revolution widened the space of what is possible. Biotechnology, the University of Informatic Sciences, and the "Into the Neighborhood" doctors would not have been possible in the 1960s.[24] It took three decades of socialist construction to make it possible. From that basis, we can glimpse the possible country we can build: a just and solidaristic society with a healthy and educated population, sustained by a high-tech economy based on socially owned companies, and a protagonist of Latin American integration.

CHAPTER 9

The High-Technology Company and the Management of Discontinuities

"Science, and the products of science, must one day occupy first place in the National Economy."

—Fidel Castro, 1993

OUR MOTIVATIONS

In debates before 2012 and in the founding documents of the Superior Organization of Business Management (BIOCUBA-FARMA), a term that we had hitherto rarely used often emerged: the high-technology company, or more specifically in our context, the socialist state high-technology company. This concept captures a three-decade experience (1981–2011) and, at the same time, establishes strategies for at least the next three decades. Cuba's biotechnology sector emerged not only as an assortment of drugs, vaccines, and novel diagnostics but also as a new type of scientific-productive organization.[1] It is characterized by:

- The integration of scientific research, product development, production upscaling, and direct commercial management, all in the same organization

- Exports to various destinations (in more than fifty countries) and a range of negotiation models for such issues as factories abroad and intangibles
- The production and export of novel products, many of which emerge from scientific research
- Highly qualified labor power
- Low export cost per weight
- High labor productivity
- Close links to the Cuban health system
- Economic management that differs from the budgeted and classic business schemes

Planning for this organization's future will require us to complete the course begun by the Cuban Revolution regarding the investment of large economic resources to form human capital and ensure that it translates into economic growth through an export and high value-added economy.

In today's industrialized nations, the direct impact of science on production began with chemistry, drugs, electronics, and communications. This occurred initially in laboratories in large industries that financed innovation and later shifted to computer science and biotechnology. In the second half of the twentieth century, a new type of company emerged, built with venture or even speculative capital, designed to transform a certain scientific or technological discovery into marketable products. In macroeconomics, this type of company gave rise to a new stock market, the NASDAQ, an alternative to the classic New York Stock Exchange.[2]

The Cuban experience is different. In a country with no prior significant industrial development, we invested heavily in human capital training and state-financed scientific development to build high-tech production capacities in state-owned companies, which were to achieve profitability by operational efficiency, not financial speculation. The analysis of that experience (which we must develop) will be a great asset in the current Cuban economic conjuncture, wherein we must defend the victories of socialism

with the weapons of economic efficiency and growth. The guiding thread of our reasoning leads us to the following positions:

- As stated in the "Economic Policy Guidelines" approved by the Sixth Congress of the Communist Party, the state socialist company is socialism. The social ownership over the means of production and the distribution of social production according to labor is expressed through it. Its viability is socialism's viability.
- Given our population's demographic (and cultural) structure and scarce natural resources, our manufacturing companies must have a high technological capacity and generate high-value-added products.
- Given the small size of our country (and hence our domestic demand), this technological company must be export-oriented to be profitable.
- The response to these challenges entails a close tie between science and the economy.
- This process cannot be gradual. The dynamics of the world economy (and of technologies) imply the need to move quickly and accept this acceleration's risks.
- Our starting point is strong: we have competent and motivated human capital, the social cohesion built by the Revolution, and majority support for the social project.
- Human capital is a necessary but not sufficient condition. In addition, we must build the kind of organization (microeconomic) and regulatory context (macroeconomic) that enhance the integration of science and the economy.
- The social achievements of the Cuban Revolution are enormous. They are not contested by friends or foes. We Cubans have placed our small, third-world country (which, on top of everything, is under attack by great powers) among the "High Human Development" nations.[3] Our life expectancy and educational attainment figures are far above those expected by the correlation with the economy's GDP. And we could offer

> abundant similar data. But this human development has not proportionally translated into material and services production growth. We still have a GDP per capita equivalent to that of nations with lower educational attainment and below that of nations with similar qualification levels.[4]

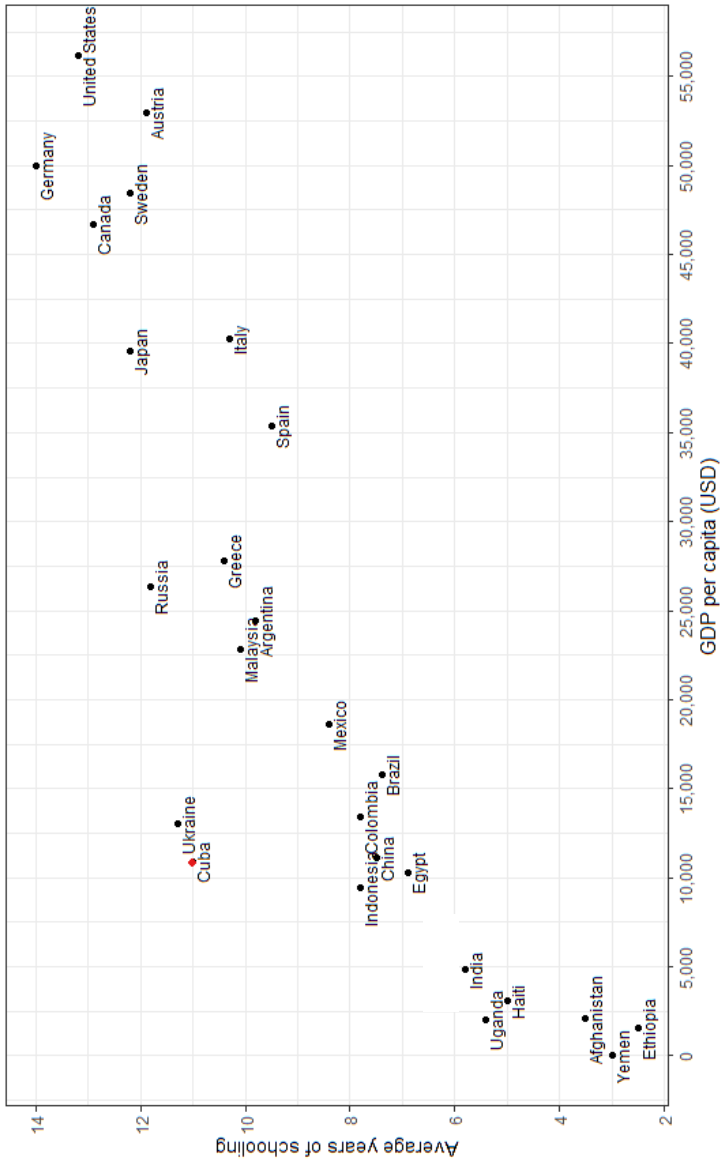
To rectify this situation, our task is to ensure that the socialist state high-technology company T is managed differently microeconomically and regulated differently macroeconomically. Its interactions with the budgeted scientific world, especially with universities, constitute its other sphere of specificity. Let us try to extract insights from the experience of the last years about how this kind of company must be led and regulated, as well as how to articulate the reciprocal enhancement of academic and university-based scientific research.

THE ECONOMIC CHALLENGES OF SOCIAL REVOLUTIONS

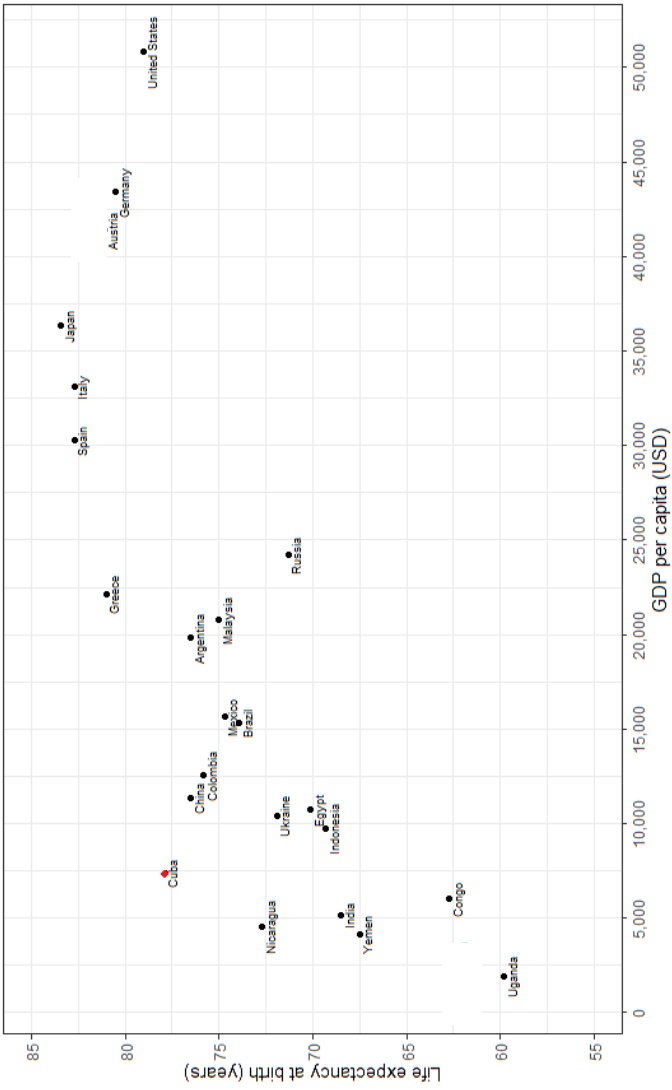
The great socialist revolutions of the twentieth century did not occur in the industrially advanced countries, as Marx foresaw, but rather in economically backward countries: Russia, China, Cuba, and Vietnam. This forced them to put at the top of their priorities, in addition to the social liberation and distributive justice that motivated them, an agenda of accelerated economic development. Without the latter, the contribution of revolutionaries would be reduced to "socializing poverty," something morally defendable but politically unsustainable in the long term. Historically, this is how the connection between social revolutions and modernization emerged.

Revolutions did not take place simultaneously in various countries either. The economic development agenda had to be implemented in conditions of isolation and hostility from countries with more economic resources. In this context, the revolutions in power must determine the resources and priorities assigned to social investment (education, health, social security,

EDUCATION AND GDP[5]



LIFE EXPECTANCY AND GDP



housing, employment protection) and the resources they can use to develop economic infrastructure. In the short term, both types of objectives come into contradiction; the more acute the needs, the more limited the resources.

The first five-year plans in the Soviet Union during the 1920s and 1930s were Promethean attempts at rapid industrialization. China's economic leap in the 1950s was another attempt, which entailed considerable social and human costs. In Cuba, with a different history and approach to the same contradiction, the heroic defense of equity and the social conquests of the Special Period in the 1990s forced us to reduce the investment rate to almost 10 percent.

In repeated historical experiences in various countries, the aspirations for equality and prosperity have been difficult to reconcile. But in the medium term, there can be a turning point after which past investment in social development and equity becomes a lever for economic growth. From there, the contradiction can be overcome, and social development and economic growth enhance each other. That is the point we must get to.

STATE OWNERSHIP AND SOCIAL JUSTICE

Another contradiction often arises between social equality and economic efficiency, establishing an equality threshold beyond which labor productivity deteriorates. Capitalism embraces this contradiction with cynical enthusiasm. It also recognizes the usefulness of unemployment and immiseration as work incentives.

One of President Ronald Reagan's favorite economists wrote in 1981 that "the crucial role of the rich in a capitalist economy is not to entertain and titillate the classes below, but to invest . . . In order to succeed, the poor need most of all the spur of their poverty."[6] The evolution of neoliberal capitalism over the last few years illustrates how that ideological notion has been implemented. The gap in mean per capita incomes between high-income and low-income countries increased from $18,525 in 1980 to close

to $32,900 in 2007 before falling slightly to $32,000 in 2010. The absolute gap between incomes per capita of low- and upper-middle-income countries more than doubled between 1980 and 2010, from around $3,000 to $7,600.[7]

The economic crisis of the 1990s after the dissolution of the European socialist bloc taught us, among other things, the strength of the Cuban people's support for the socialist project, despite the hardships of the moment. Between the choice of well-distributed austerity among all or the enrichment of a few at the expense of the rest, most Cuban people chose justice. Our economic growth must continue to guarantee and expand our social successes. Here is where the question "how to do it?" emerges. Social development needs resources, which cannot only come from taxing profits of the non-state sector. Moreover, sustaining social justice through taxes on profit has an intrinsic contradiction. To collect more taxes, we would need to accept the existence of a sector with large profits, equivalent to the expansion of inequalities.

The value created by state companies is the only guarantee of social justice. It is true that we can and must maintain within the state economy a relationship between the personal contribution to work and personal income (the well-known formula of "to each according to their labor"), but this would be a less rigid relationship than the linear relationship between profits and taxes and would accommodate a greater margin of wealth redistribution. There is an inverse association between equality and work motivation for low levels of social consciousness and scarce technological development, but cultural and technological development can overcome this apparent contradiction.

The mediation between equality and productivity is driven by two factors: the culture (values) of the people and the regulatory framework of the economic system. There also is an inverse relationship: the more values of solidarity and love for work are rooted in culture, the less regulatory pressure we need, and vice versa. A cultural vacuum cannot be filled with regulations and centralization, even if it is the product of good intentions. Many socialist

experiments worldwide have collided with this cultural limitation. For socialism to be viable, a culture is needed in which individuals find motivation for work and creativity in their contribution to the quality of collective life and the long-term contribution of their work. This is why socialism is essentially the fruit of culture. We Cubans have progressed in constructing such a culture, as is evident in many of our population, despite the strains that appear here or there. This is another lesson of the special period, and it is our launching pad for what is to be done next.

THE MANAGEMENT OF TECHNOLOGICAL DISCONTINUITIES

Our economic strategy must be based on human capital and shared values. One of its strategic guidelines should be the expansion of economic sectors with high labor productivity and export potential based on direct interaction with science and technology. In these sectors, it is not a matter of achieving incremental advances by perfecting what we have. It is a matter of generating a change in the growth rate, a discontinuity that does not come from extrapolating past trends, even good ones. For this, we need high-technology companies.

Economic discontinuities at particular moments are rare, but they are a regularity in the longue durée of history. The rise of the modern industrial economy was a massive discontinuity in economic logic. It is usually recognized that it was based on industrial inventions (the steam engine and others), but in fact, it also was based on long-distance trade (from geographical discoveries) that achieved super profits by connecting a supply and demand that until then ignored each other. It was not the product of improving the artisanal economy and subsistence agriculture. More recently, oil catalyzed economic discontinuity in some countries. Foreign investment, using abundant and cheap labor in Asia, also introduced discontinuity and created new supply and demand slots, which was more successful in some countries than others.

Based on the direct connection of the scientific and business worlds, the knowledge economy sketches a new opportunity today. And it is the high-technology company that arbitrates between innovation and its economic value. In this case, discontinuities are not generated from the extrapolation of earlier tendencies but from leaders' vision. Fidel Castro's decisions to create the Scientific Pole of Biotechnology and then the University of Informatic Sciences are clear examples of this point.

At the level of grassroots organizations, concrete examples in recent decades of this management of economic discontinuities have changed their existence. Let us see some of them:

- In 1989, the meningitis BC vaccine made Cuba a vaccine-exporting country. In fact, it prompted the creation in 1991 of a new organization, the Finlay Institute.[8]
- The export takeoff of the Center for Genetic Engineering and Biotechnology resulted not from improved efficiency in producing interferon (which did occur) but from introducing novel products such as heberprot-P and the pentavalent vaccine.
- The export takeoff of the Center for Molecular Immunology did not come from improved rodent monoclonal processes but rather from an innovative approach in negotiations with Brazil, China, Canada, and other countries.
- The increased production of several generic drug plants was another discontinuity, in this case catalyzed by linkages to Latin American health programs through an innovative regional integration strategy.

In fact, the development of the Scientific Pole has been a succession of discontinuities implemented by a new organization created for that purpose. The environment of special regulations and the high attention to the Scientific Pole in its first two decades allowed us to seize the opportunities given by these discontinuities. A research-production organization oriented toward the export of innovative products requires internal management processes

that consider its differences from other production and service companies:

- Export-oriented organizations conduct research and product development at a higher rate. This fixed cost must be subsumed into the volume of their earnings. The tendency to reduce this cost in periods of limited sales must be resisted.
- Research and product development entail uncertainty: some succeed, and some do not. The management system must have a greater margin of tolerance for project failure. Otherwise, only minor incremental innovations will be undertaken.
- Short-term profitability depends, as in other companies, on the efficiency of production processes and attention to markets. However, profitability in the medium term depends on the appearance of novel products that can penetrate new market niches through negotiations, which also contain uncertainty.
- Labor productivity cannot be assessed solely by the well-known formula of Gross Value Added (GVA) per worker. That reflects current productivity, but a company must also evaluate the effectiveness of its actions to guarantee tomorrow's productivity and the sustainability of productivity. This frequently translates into research and development projects or the development of quality systems, which, seen through a myopic lens, reduce today's GVA. They both depend more on the productivity of the knowledge worker than on the productivity of manual labor.[9]
- Competitiveness is not based solely on costs but mainly on product differentiation.
- Their planning capacity is limited, given that, among other things, the demand for products that do not yet exist is, by definition, unknown. On the other hand, being export-oriented companies (dependent on the imports of specialized inputs), their external insertion is essentially financial and not reducible to material planning.
- Direction management cannot be limited to controlling planned events that must occur. Rather, it must deal with actions that

increase the probability of certain events that change the setting, such as the success of a new product or the implementation of a new negotiation scheme. These are discontinuities, and attaining them is an inherently probabilistic process.

- Entry into the market of a product whose performance and demand are unknown requires actions at all company levels, which are difficult to specify in advance. This is why workers must be committed to objectives rather than tasks.
- Achieving goals on a road paved with uncertainties depends not only on discipline but mainly on creativity, which in turn depends on motivation.
- The organization relies much more than others on extramural networks. In other organizations, these extramural links are essentially with suppliers and customers. But in companies that depend on developing new products, there are actions vis-à-vis scientific research and product evaluation (or, in the pharmaceutical industry, clinical trials) that cannot be internalized and can involve dozens of extramural actors.
- Production processes are usually as novel as the products and lack external references to evaluate their efficiency. The practice of a new production process will generate an accumulation of tacit knowledge, but this is not enough. In these companies, production requires intentionally implementing actions to capture and structure this knowledge, which becomes a comparative advantage. In these organizations of permanent learning, human capital is not a cost but the main asset. Costs must always be reduced, but assets must be increased.

Integrating science and the economy will affect how grassroots productive organizations are structured and managed. When productive forces change, so do the forms of organizing economic activity. Thus, with agriculture on a commercial (and not subsistence) scale came the farm, and with transformative energy-based industrial technologies (steam, oil, electricity), the modern factory emerged. The question now is, what organizational form will

emerge from the increasing integration between science and the economy? It is obviously not the twentieth-century company, nor is it the research institute as we know it . It must be something new. And that is the state socialist high-tech company.

In the twenty-first century, technological complexity renders impossible the free associated producers model of the nineteenth century. High technology is not the space for cooperative ownership. Even the capitalist company, although promoted as the example of success in the specialized literature, has not proved to be an efficient form of organization of the knowledge economy either. In biotechnology, for example, fewer than 20 percent of companies have become profitable from their sales.[10] The short-term approach—the privatization of knowledge, the response to "market signals," and the need for a constant increase in profits characteristic of a capitalist company—do not work well when it comes to connecting science and the economy, managing risk-bearing projects, taking care of human capital, and prioritizing long-term investment. The solution to this contradiction in the developed capitalist countries was speculative investment, which mobilizes capital through the issuance of shares and seeks profitability not in the real economy but in speculation, by overvaluing and reselling those shares. Thus, financial bubbles are created that one day reach the limits of constant overvaluation and burst, as occurred with internet services companies. Even in market economies, the economic successes in the postwar period (Japan, Singapore, France, and others) were examples of industrialization carried out with government support, direction, and even management.

The relationship between the level of development of the productive forces and the relations of production is one of the main discoveries of Karl Marx. But in the literature that followed, there has been little discussion of the various mechanisms for this relationship. The experience of the biotechnological industries tells us that these mechanisms have to do with how knowledge is captured and circulated, the relative role of knowledge in individuals

(who can move in relation to the market), and in the interaction networks in and outside companies, which are not salable or comparable. As technology becomes more sophisticated, technological knowledge becomes more social, which demands higher forms of production organization and relations between producers and the means of production. And there, we can see that the path to the future of economic systems passes through socialism.

CONSTRUCTING THE CONTEXT

It could be argued that the particularities of a high-tech company that distinguish it from other production and service companies are ultimately quantitative. Any of the nearly three thousand companies in Cuba could have a research and development component in its expenses and base its strategy on introducing innovative products that replace current leading ones. This is true, and in fact, the development of various sectors of our economy can and should gradually incorporate features of the knowledge economy. But it is important not to dilute the concept.

Any industrial activity is ultimately connected with science, with the creation of knowledge at some time in the past and elsewhere. But, as this connection shrinks, a company's economic performance depends on the research and innovation that have occurred in the company itself and in the past five to ten years. The innovative process becomes so continuous that the cost of developing new products becomes an ever larger and indispensable part of the cost of production. From there, science enters the company's management processes, and things begin to be different. After a certain threshold of scientific activity is reached in the company, and a certain dependence develops between the export strategy and the new products arising from that scientific activity, the company begins to change, requiring different internal processes and external regulations.

There may be no more than twenty to thirty exporting companies with innovative products, internal scientific activity, and

high labor productivity constituting 1 percent of the Cuban state business apparatus. That there are not many of these companies gives us room for creativity in organizational design and its context. We must determine how to create a regulatory environment that enhances the performance and expansion of this type of company. It must be specifically designed for this purpose. A country's regulatory framework is built from knowledge based on correct extrapolations of the preceding average performance for the incremental improvement of companies and does not consider the appearance of discontinuities (of products or markets) that could radically change the life of companies.

These discontinuities are perceived by conventional microeconomic theory as rare and risky events that arise from external causes. But, for high-tech companies, the daily generation and management of discontinuities are precisely the reasons for their existence. We need a subset, however small, of our business apparatus to operate based on the creation of those discontinuities, in which:

- A higher level of research and development investment is assumed and encouraged, including business financing of joint projects with academic or university institutions.
- The uncertainty (and apparent waste) implicit in exploring new products is tolerated.
- Greater priority is given to cost reduction.
- Research and production are based on external demand, not only domestic demand.
- Innovative (even risky) internal and external negotiation schemes are explored.

A regulatory context that fosters constant profitability increases per worker, the limitation of the workforce size, reduced unit costs, precision in material planning, and the guarantee of minimum risk in negotiations may be convenient for most of the national economy, but it can suppress the development of high technology. In a

letter to Fidel Castro in 1965, Che Guevara criticized the lack of connection between science and the economy in the Soviet Union. "Technique has remained relatively stagnant in the vast majority of Soviet economic sectors. . . . In the Science Academy of that country, hundreds of accumulated automation projects cannot be put into practice because the factory directors cannot allow themselves the luxury of their plan failing for a year. . . ."[11]

Imperialism's economic war against Cuba and the crisis that ensued after the dissolution of the European socialist bloc have understandably fostered a mentality skeptical of risk and uncertainty. And we need this mentality. However, we can and must also make room for managing economic discontinuities despite the uncertainty and risk it entails. The ability to creatively manage this contradiction is one of the advantages of the social ownership of the means of production and the state's role in the economy under socialism. We must not relinquish this advantage.

Under capitalism, private property and neoliberal ideology reduce the state's role in the economy to managing a few macroeconomic variables (money issuance, interest rates, tax policies, etc.) influencing a company's life. Under socialism, social ownership of the fundamental means of production allows for the effective, differentiated treatment of certain sectors and projects based on the medium term, thus escaping the short-termism characteristic of companies guided by the constant increase in profits. Let us make the most of this advantage. The socialist state high-tech company is the instrument for doing so. It must expand the room for business scientific research and its direct impact.

In industrialized countries, the tendency in the last decades has been toward increasing corporate participation in science financing. The underdeveloped nations of the Global South have not only had fewer resources for science but also these resources have come from state budgets. The corporate component of scientific investment was estimated (in 2012) to be more than 80 percent in Japan and 68 percent in the United States, while in Latin America, it is 43 percent and 15 percent in Cuba.[12] This

situation must change, and the high-tech company will be the main change agent. But it is not the only instrument for development. We must also seek to enhance the impact of budgeted scientific research, especially university research, stemming from the budgeted scientific centers.[13]

To respond to the country's strategic needs, Cuba's system of science, technology, and innovation cannot be small. It must grow beyond what would be expected given our economic conditions (exactly as we have done with the educational and health systems) and beyond the explicit demands of production and services. Otherwise, it could not effectively connect with global knowledge flows and assimilate contemporary scientific and technological progress. It would be a mistake to reduce the volume of scientific activity based on arguments of economic rationality. Human potential must continue growing to "pull" development and then establish creative ways to finance its operation.

Historical experience shows that whenever high-tech companies aimed at transforming scientific research into high-value products and services have emerged, they have been supported by prior and simultaneous state investment, not only in the formation of human capital but in the investment in non-commercial scientific research. Even in the United States, a benchmark for market fundamentalism, the best-known examples of high-tech companies in information technology and biotechnology were supported and continue to be supported by state investment in science. This support has been channeled through the U.S. Defense Department's Advanced Research Projects Agency, which funded the first iteration of the internet, and the National Institutes of Health, which funded the Human Genome Sequencing Program.

In Cuba, the emergence of biotechnology was supported by the scientific capabilities created over two decades with state resources at the National Center for Scientific Research, the University of Havana, and in various institutes of the Ministry of Public Health. This budgeted (and exploratory) component of national science must continue to exist and grow. It is not a process detached from

the interaction of science with the economic model; it is a component of that connection.

We must also design our model regarding the links between budgeted scientific institutions and companies. As I write these lines, it is still unclear what this model should look like. We know what it should not be, though. It is not about reproducing market relations in which universities patent everything and then negotiate patents with Cuban companies. That late capitalist scheme promoted in the 1980s by the neoliberal Republican administrations in the United States has been increasingly criticized for its inefficiency, given the increased transaction costs it generates in the economy.

The relationship between socialist companies and universities cannot be market-oriented. But neither can it be an artisanal project of small production enterprises in university areas based on their scientific know-how but lacking the know-how to transform a scientific innovation into an exportable product or service. Once again, much depends on the wisdom with which we design a regulatory framework that stimulates, in our specific context, the relationship between universities and high-tech companies. This could be expressed through creating company laboratories in universities and teaching units in companies, in a system of cross-institutional mobility of professionals, in business funding of joint projects, and in many other ways we will have to explore.[14]

This will demand a lot of creativity since there are no recipes for the Cuban context and our objectives. The economic discontinuities that promoted the takeoff of today's industrialized countries were created by wars of conquest in search of markets and raw materials. Others came from discovering large reserves of natural resources (oil and others), which we do not have. In other cases, the inflection was produced by foreign investment attracted by abundant cheap labor. This will not be our path either. We can try to manage economic discontinuities based on endogenous scientific research and the abundance of highly qualified human capital. But we do not have any manual for this purpose. In 1830, Simón

Rodríguez, Bolívar's tutor, expressed the following idea that is still valid today and fitting as a conclusion to this chapter. "Where will we go to look for models? Spanish America is original. Its institutions and its governments ought to be original. And original the means to find both. Either we invent, or we err."[15]

CHAPTER 10

Management in the High-Technology Company

"New worlds must be lived before being explained."
—Alejo Carpentier

The concept of the high-technology company first appeared in an official document in 2021, in a decree-law that established the Higher Organization of Business Management, bringing together the Scientific Pole of biotechnology and the pharmaceutical industry. The high-technology company, a new constituent of the Cuban socialist economy, was a major change. Its scope extends beyond specific sectors and helps strengthen the socialist state company as the central axis of our economy.

The HTC did not arise from theory but from the experience of developing Cuba's biotechnology industry. The central idea of this chapter is that since 1981, Cuban biotechnology, well known for its innovative biopharmaceuticals and vaccines, has been innovative in its organizational management. The guiding thread of such innovation was the need to build efficiency, not only in production but also in the connection of scientific research with production and exports. In this sense, many aspects of this experience could

be generalized beyond the context of biotechnology in an economy whose effectiveness will increasingly depend on the creation and circulation of knowledge.[1]

Several current directors of Scientific Pole institutions, like myself, moved from a budgeted academic institution to an organization that investigates, develops new products, produces, increases production, exports, and establishes a positive export cash flow. I will describe what we learned to make this transition.

THE BASIC ECONOMIC ORGANIZATION OF THE KNOWLEDGE ECONOMY

The high-technology company is distinguished by its purpose of obtaining and producing novel products, which are quickly replaced by better ones, stemming from a greater intensity of scientific research largely in the company itself. It is also distinguished by the structure of its human resources, the complexity and specialized nature of its interactions with the demand sphere, and the diversity of its negotiation models. The growing integration between science and the economy is expected to have consequences for how grassroots productive organizations are structured and operate.

Historically, the emergence of new productive forces has always generated new relationships between humans vis-à-vis labor. I am not referring here to an entire society's productive relations, but to the consequences of these changes in the microeconomics sector, that is, in the basic organization of production and services. When farming ceased to be self-sufficient and commercial agriculture arose, the farm as a productive organization emerged. Later, energy-based transformative industrial technologies (steam, oil, electricity) gave rise to the modern factory. What organizational form will emerge from the increasing integration between science and the economy? Probably not the company of the twentieth century nor the research institute as we currently know it. It must be something new.

Let us see what gradually emerged in the real life of Cuban biotechnology in the thirty years after Fidel Castro inaugurated the first centers in the 1980s. These are the traits we can identify:

- Whole-cycle integrated organizations that conduct research, develop products, and produce and commercialize their production under the same management.
- Organizations with direct export activity (products distributed in Cuba a fraction of what is exported).
- Organizations with decentralized financial management, each with bank accounts in domestic and foreign currencies and responsible for building and maintaining a positive cash flow, financing production and research, and generating a surplus.
- Portfolio of exportable products based on innovation and scientific research.
- Attention to the product line, that is, to products marketed today and those in development.
- Direct linkages to health programs and food production in Cuba.
- A highly qualified and motivated workforce and an intense internal training program.
- A culture of dedication to work driven by an ethical sense of social duty and motivation.
- Organizations wholly owned by the Cuban socialist State and which have an intense internal political life.

Note that these organizations do not have the traditional structures of companies or budgeted scientific centers. They are both things at the same time, and neither. As companies, they must produce high-quality products and export them, be profitable in both currencies, lower costs, and constantly increase work productivity. But they also have to invest heavily in research and development and training, take on risk-bearing projects, be linked to social programs, pay attention to the long term, and make their human capital grow quantitatively and qualitatively. The organization

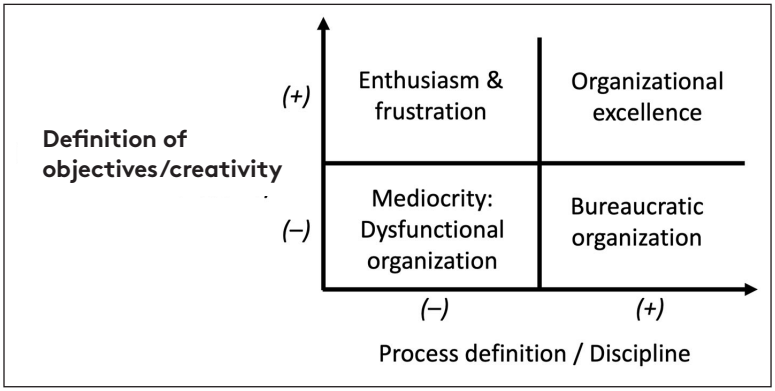
must be capable of simultaneously cultivating all these often-contradictory processes. This poses a challenge vis-à-vis the relations with the national regulatory environment, which, since it reflects the average conditions of our economy, frequently pushes in one direction or another. At the same time, it is also a challenge to the internal administration of organizations where the different work cultures of the producer, the scientist, the regulator, and the merchant must coexist (and be promoted).

MANAGEMENT PROCESSES AT THE BASE

The center I use as a case study, the Center for Molecular Immunology (CMI), exhibits the eight traits described above. How is an organization of this type managed in everyday life? Let me summarize what we have learned by examining a positive experience without any pretensions to theorize or to turn it into a recipe. I will simply describe what we learned and what worked.

There are two orthogonal axes of organizational excellence. There are excellent organizations in formulating sound objectives that motivate people, but they are mediocre in creating processes to pursue them with discipline and perseverance. Some scientific centers are like this and go through phases of great enthusiasm, given the attractiveness of their objectives, followed by frustration because of the inability to achieve them. Other organizations create a culture of organization, systematic processes, and discipline but do not formulate objectives that stimulate creativity and become bureaucratic. At first sight, what is done on one of these axes may seem contradictory relative to what is done on the other. Yet this is a contradiction that, like any other, has a creative core that we must know how to find. The basic economic organization of the knowledge economy is one where creativity and discipline coexist, a combination that also can be described as the "formulation of objectives and the construction of procedures."

Every organization must clearly communicate its mission (why we exist . . .) to its workers. Many organizations have written



mission statements. We do too. But for the mission statement to work, it must be operationalized by formulating a vision of the future, describing how we see ourselves in x years. Formulating a vision statement is not like making a five-year plan. The vision is more than a plan, which is by definition, something considered possible. The vision contains elements whose scope we cannot accurately calculate, as it is subject to internal and external uncertainties. It even includes bold goals, which some might deem unrealistic. But those are precisely the ones that capture people's imagination and commitment. Fidel Castro was a master at formulating visions that mobilized the creative energies of Cubans. Everyone must learn from this and try to apply it at their level. An essential characteristic of the organizational vision is that it must be simple. We must formulate it in terms that everyone understands. They are for everyone, not for specialists. People must remember it and explain it to their families at home.

The vision is not at odds with the plan. It is rather the other way around: a clear (and bold) vision is what allows planning in a distal to proximal sense, that is, starting from an understanding of where we want to be in x years and deducing from there what we must do today and in the upcoming years. The grassroots organization of the knowledge economy needs to know where it is going in ten years to decide how to work today.

From the mission comes the vision and from it, the objectives. But we do not want to limit ourselves to the vertical axis that leads to frustration. After the objectives, we must develop the procedures. Procedures define an organization. They are its "physiology." Some 1980s literature on company management insisted that good ideas about products create good organization. More recent studies have reached the opposite conclusion: excellent products do not create an excellent company but are their consequence. It is organization that facilitates the emergence of new ideas and their implementation.[2]

Managers of this type of organization cannot limit themselves to solving problems. They must solve them, of course, but also determine how and what must be done so they do not recur. This manager is a permanent "process builder" within the organization. I am not referring here to production processes but to management processes. Each organization must define its own. By way of illustration, these are the eleven essential management processes that we identified in the CMI:

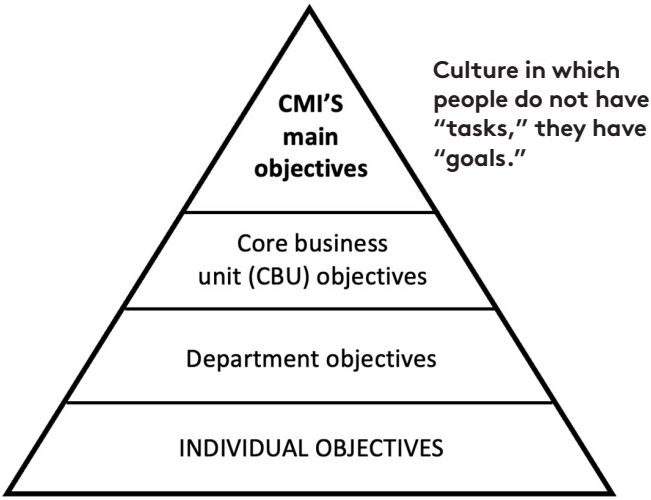
- Formulation and control of the key objectives.
- Financial management and internal control.
- Management of productive and commercial activity.
- Logistics management and continuous material balance.
- Quality management.
- Attention to mixed companies and negotiations.
- Project and product management.
- Managing scientific activity.
- Clinical research management.
- Services and investments management.
- Permanent development of human capital.

Each of these processes contains its own procedures and indicators. Procedures describe how things are done; indicators tell us how they are measured. Processes have two features that, for us, have yielded innovation. Processes are activities that horizontally

traverse different organizational units (departments, sections), which must act together to work. The manager's main task is to direct the processes, not the organizational units subordinated to it. The spontaneous tendency of complex organizations is that each manager seeks to optimize the operation of the section they direct, which can lead to a sub-optimal operation, with frequent conflicts in the interfaces between one unit and another. The top manager must devote intelligence and energy to correcting this trend. Optimizing the whole is often not equivalent to optimizing the parts.

Identifying essential processes requires intellectual effort and discussion. At this point, some readers may think, "Everybody knows that." In a complex organization, countless interactions among its components occur daily. Some are essential to fulfill their missions, and the manager must discover them. They constitute the process model, which gives us a very different (but complementary) view of the organization from the organizational chart. In such an organization, people do not have tasks. They have objectives. Researching and developing new products, producing them through processes that are not initially known, and placing them in markets that do not expressly demand them, contains a lot of uncertainty and calls for creativity. No one can define *a priori* the tasks that guarantee the attainment of a certain objective. Each manager and each worker must be committed to the objective and be able to design and implement the required tasks.

The objective formulation process occurs from the top down, beginning with formulating the company's objectives and continuing with formulating the objectives of the units, departments, laboratories, and so on until reaching the individual objectives. The process is directive, which guarantees the alignment of the objectives with the organization's mission. But the process also is participatory. Managing this apparent contradiction between the directive and participatory character of the formulation of objectives is another of the challenges to the creativity of the leaders and to their communication capacity. People must know the objectives,


CMI'S main objectives
Culture in which people do not have "tasks," they have "goals."
Core business unit (CBU) objectives
Department objectives
INDIVIDUAL OBJECTIVES

participate in their formulation (and perceive this participation), and commit to them. An organization where everyone only knows and does their part, even if they do it well, is a nineteenth-century entity that no longer works.

An objective that is neither communicated nor shared may exist on paper but not in the organization. Goals describe priorities. Their identification is not simple since priorities reflect the intersection between what is important and what is possible to achieve. Two things are associated with each main objective: its funding and a critical path toward it. It took a lot of effort (and caused much resistance) to abandon the tradition of allocating funding to units and departments (from which the financing of objectives was obtained) and transition to the allocation of funding to the objectives (from which the resources needed by the units derive).

Defining the critical path follows the formulation of objectives. The critical path is the sequence of events that must occur. It is not a question of describing all of them but of sequentially concatenating the main milestones, those for which there is no "room," that is, those whose delay will retard the achievement of the objective. Discussion about the annual plan concludes with the objectives

pyramid, financing by objectives, the objectives' critical path, and the pyramid of indicators. With the right practical experience, everything can be done in the year's first month.

Each organization compiles quantitative indicators that describe its activity and make up some sort of organizational dashboard. Books have been written about this topic.[3] Here, it suffices to underscore our understanding of correctly choosing and reviewing indicators systematically. There cannot be many indicators. Otherwise, they will not function as a dashboard. The organization generates, literally, thousands of pieces of data. Only a few are essential, and we must choose them very carefully at each level since only what is often measured is optimized properly. Each indicator is associated with a current value (today's) and a target value (what it should be). This completes the preparation of the plan. What follows is how these indicators are used. Then, throughout the year, each board of directors always begins by reviewing the main indicators, the main objectives, and the critical path toward the objectives. Then, other topics are discussed according to the agenda. If this is done monthly, the indicators and objectives are reviewed about ten times yearly. This controls for one of the main risks of this creative organization: losing the main objectives.

The commercial strategy challenge is to find the niche for unfulfilled demand. When we talk about commercial strategy, we are talking mainly about exports. These high-tech organizations are either exporters or they are not. High-tech organizations must subsume high fixed costs of research and development, and complex quality systems, in their operations. This is only possible if the economic operation is large, which is not supported in most cases by the domestic demand of a country of eleven million inhabitants. Thus, except for food production, which is in great demand, for most goods with a certain technological complexity it is more expensive to produce in Cuba than import.

The second idea is that the centrality of the commercial strategy changes over time. At the risk of oversimplifying, when an organization of this type is founded, the main issue is the research

and development strategy: either we have or do not have innovative products. Then the main bottleneck shifts to the production capacity and the quality system accompanying production. But when these two stages are successfully transited (we already have innovative products and can produce them), the bottleneck shifts to exports: there will be growth (and refinancing of research and development) if we have demand for products. That is the challenge of marketing. How do we face it? There are no roadmaps, and a long road of trial and error awaits us.

Moreover, the existing marketing literature doesn't address many things we need to do. We will obviously have some approaches that overlap with those of equivalent companies in the North, as some technical components are universal, but our main approaches must be different from what is usually understood by marketing. There are two reasons for this: capitalist companies are interested in solvent demand (that is, the demand expressed by those who can pay), and, with their financial power, they quickly occupy and defend that space. The other reason is that these companies guide their decisions by their economic impact rather than the social impact of their goods and services. That is not our way. By that, I do not mean that we renounce profitability, but our search for export space must identify unsatisfied and seldom expressed demands. This leads us to seek collaborations not only with distributors in the destination countries but also with the social actors involved with the final impact of goods and services. Our large commercial operations have corresponded to this type.

Exploration and exploitation are two research and development lines. The organizations of the mainstream economy operate with the concept of product portfolio, which includes what products the companies offer. In the knowledge economy, this idea is broadened to encompass the concept of the product pipeline, which includes current products and future ones in different stages of development. Thus, for example, in a pharmaceutical company, the product line contains what is distributed and exported today,

what is in the clinical trial stage but not yet registered, and what is being tested in laboratory animals. Products transition from one stage to another (although some will fail and not transition), and the effectiveness of the research and development leadership depends largely on the ability to achieve those transitions with the necessary speed.

Product line management comprises most, but not all, scientific activity. Scientific activity has two components, and management processes must address both. The first component is what we have described as product line transitions. This is a deterministic process: we know fairly well what we have to find out about a product to decide when it enters a clinical trial and when we propose it for registration. This is a process of exploitation of previous scientific results, which can be structured and planned. But there is another component of scientific activity that is essentially probabilistic and seeks to explore new fields, answer basic scientific questions, and gain new knowledge that may lead to a product. These organizations require innovations and discoveries, and a certain proportion of exploratory scientific activity must be maintained. Throughout these years, we have learned that although both components of scientific research (exploration and exploitation) occur in the same laboratories, they cannot be mixed. They must be conducted separately to avoid the risk that all effort will be concentrated on the product line and thus, discoveries that could lead to great advantages never occur and the opposite risk that effort is concentrated on basic science and does not generate products. To maintain this delicate operational balance, which depends on simultaneous attention to short-term and long-term success, both aspects of scientific activity must be analyzed in different realms.

An organization basically must conduct two activities: processes and projects. Processes are cyclical activities (to produce, assess quality, obtain inputs, train and evaluate personnel) wherein standardized procedures and efficiency indicators are developed to compare one cycle with the previous one. Projects occur only once

(to develop a new product or execute an investment). Directing a project is an unrepeatable transformation. Because of their repetitive nature, processes can be directed by organizational units. Projects, however, include activities that cross several structural units of the organization, and this is a source of friction in the interfaces between one department and another involved in the same project.

In traditional economy companies, most management work consists of directing the processes for which the companies were created. In knowledge economy companies, processes that need to be optimized and projects that transform the company occur simultaneously. Processes are directed by the managers in charge of the units created for them. Projects have demanded the appearance of a new and useful organizational figure: the project director.[4] Their task is to know and manage all the information relevant to developing a project, maintain a holistic vision through all the functional units, anticipate bottlenecks, elaborate and evaluate decision alternatives, and ensure that the right decisions are made on time. Project managers are information managers and decision brokers. They are essential in complex organizations for two reasons. First, unit heads tend to decide what is optimal for their unit's work. But optimizing the parts is not equivalent to optimizing the whole. The achievement of objectives may require the suboptimal performance of one component so that another one performs better. It is very difficult for such a decision to come from a functional unit's boss. Second, realizing a project requires the participation of many experts in different fields; an expert is, almost by definition, someone lacking a big-picture view outside of their area of expertise. In complex organizations, chief decision-makers cannot be experts in all aspects of the job, while experts are generally bad decision-makers. The project manager is the one who can address this contradiction.

Industrial operations and the capture and structuring of tacit knowledge are characteristics of knowledge economy organizations. Industrial operations is a broader concept than production; it includes the management of production financing, logistics, the production itself, the primary evaluation of products, and

transportation and distribution technology. The direction of productive activity in a high-tech company probably has more elements in common with the administrative techniques of the traditional economy, having to address the same issues—productive technology, process standardization, unit operations, costs, maintenance, and storage—as any factory. However, we must highlight two specificities of high-technology companies that have consequences for management processes.

Technologies are complex. This implies that the inputs, control parameters, and yield indicators may be unpredictable. The consequence is that the management process cannot be fragmented, and though there are departments of economics, logistics, production, quality control, engineering, and distribution, each occupying different positions in the structural organization chart, someone must control the complete chain that goes from money (inputs) to money (sales): the director of industrial operations.

The productive process produces not only tangible products but also data, information, and knowledge. Technologies are always new and changing. Experience provides an abundance of knowledge that becomes a comparative advantage. But this is initially tacit knowledge that accumulates across the production process and becomes difficult to structure and communicate. For this reason, the direction of production must include systematic processes to capture tacit knowledge and convert it to structured knowledge.

In knowledge economy organizations, quality management is transformed into culture. In this field, we do what everyone else does because if anything this is standardized worldwide, it is quality systems. However, there is an overarching but often overlooked issue: everyone must understand what quality management means. A quality management system has:

- Specifications that define the attributes of a product's intermediate and final stages.
- Standard operating procedures to ensure that the product meets the specifications.

- Records that indicate how things were done each day.
- Monitoring that identifies deviations from specifications and procedures in actual production and corrects them.[5]

There is a quality system when there are specifications, procedures, records, and supervision. Of course, everything is much more complex (especially for experts), but experience tells us that when people understand these four essential ideas, quality management becomes culture.

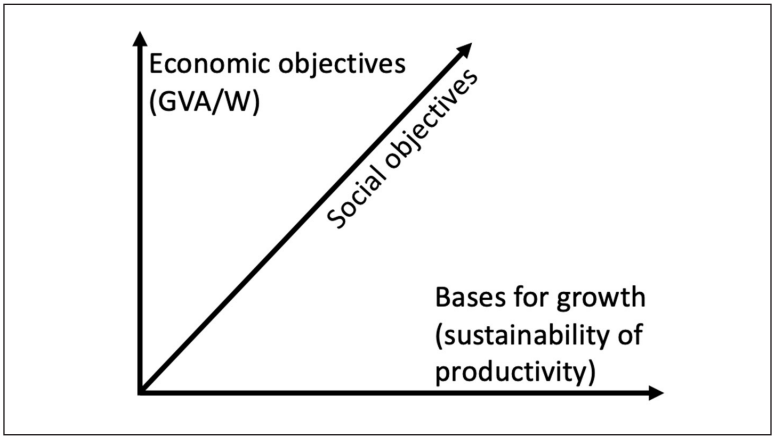
Extramural networks, such as linkages to health programs, are essential to the Cuban biotechnology experience. This is a primary social duty and a main comparative advantage vis-à-vis economic performance. To materialize effectively, this integration generates management processes. In this case, this entails the administration of extramural relations. Obviously, the control that can be exercised over a project outside a company is less than when it is executed internally, but its impact may be greater. Management processes have had to be implemented to handle this apparent contradiction between control and impact. These processes are of two types: supervision and knowledge management. We need both, and there is an inverse correlation between them: the more we manage knowledge with extramural actors, the less supervision we need, and vice versa.

The creation of human capital has been one of the great achievements of our Revolution. Investment in technology connects human capital and added value in our economy. The Special Period limited our investment capacities and generated a dissociation between human capital and its impact on the economy, inducing a downward trend in the contribution of human capital to economic growth.[6] Our recovery entails the recuperation of that connection. The high technology company will be a central actor, but it cannot achieve this recovery by itself. Its impact on the economy will depend on its ability to become a connection node between the Cuban socialist business apparatus and our social, health, educational, and academic institutions, among others.

Effectively managing these extramural processes is as important as what we do inside the company.

Ongoing training based on the demand for knowledge also characterizes knowledge economy organizations. The organization generates goods and services and also tacit and explicit knowledge and a particular organizational culture. Hence, human resources cannot be treated simply as resources; they are the main capital of the organization. This capital must be preserved, even in times of economic difficulties. It cannot be treated as a variable cost that goes up or down according to the level of economic activity. This challenge is not limited to the amount of training but also encompasses its content. The desire to increase the amount of training (as a goal in itself) entails the risk of building a system led by the supply of knowledge. This is not a bad option, but it is a limited one. The impact is multiplied if we implement knowledge-demand-driven training. This implies initially establishing the organization's knowledge and determining what is most important for fulfilling its missions and then building a training system.

There is a triple dimension to productivity. All the concepts discussed in the preceding paragraphs are about increasing labor productivity. But what is labor productivity? At first glance, the answer is simple. We have always defined it as Gross Value Added per worker. However, here we see another important particularity of knowledge economy organizations. Productivity has three dimensions. The first is the traditional Gross Value Added per worker (GVA/W). But if we limit ourselves to it, we would conclude that cutting research and development or training expenses increases the GVA/W. This is true in the short term. But in these high-tech sectors, products and technologies are replaced more quickly than in others. The success of the production system depends not only on high productivity today but also on guaranteeing the sustainability of future productivity, and we need indicators that measure this. The third dimension is found in the social missions of these organizations, wherein decisions are not guided by market mechanisms, especially in our socialist society.



Someone wedded to traditional concepts could argue that these social missions are presupposed. But we have already seen that productive organizations of the knowledge economy combine traits of entrepreneurial activity with budgeted activity into a whole. These two missions are not juxtaposed but integrated, and there are common examples (such as the diagnostic systems of the Immunoassay Center or the Cuban vaccination campaigns) where the social impact, in addition to being a duty, becomes the main lever of exports. The idea is not that these organizations are so complex that productivity cannot be measured. It means that it must be measured in another way and that the GVA/W indicator must be complemented by others. This is a controversial issue and a debate that is just beginning.

The debate is far from theoretical. Our companies are usually evaluated by indicators that analyze today's activity (profits, cost per weight, return on investment, productivity per capita) but poorly measure how the company lays the foundations for future growth and productivity. The high technology company, by definition, operates in the field of innovative products, and therefore its markets are infinite in principle. It is a growth-oriented company rather than oriented to savings or operational efficiency (although its importance cannot be evaded). Suppose we fail to design and

evaluate indicators of sustainability and growth. Then the pressure to evaluate what is measurable, to the detriment of what is important though less measurable, will inevitably impose a short-term approach to business strategies.

A direct consequence of innovation being part of the value chain is that productivity depends on creativity, which in turn depends on motivation. Attention to and permanent reinforcement of worker motivation is too important to be left to spontaneity. In cultivating motivation, no method can replace the manager's personal example and communication skills. But it is also essential that there exist many spaces for communication, where the organization's work and its implications are debated and where daily work is performed according to our country's tasks and major social objectives. This is not just about brainstorming technical issues. There also is a lot of political discussion. Our organizations have been and must continue to be highly politicized environments. That political climate is the responsibility of the managers, not only of the political organizations. Technical and intellectual motivation is good and necessary, but it is not enough. Our country's scientific and technical development only acquires meaning through its contribution to the Cuban socialist project and the defense of our sovereignty.

There are many positive experiences in the biotechnology sector, but pathologies also emerge, such as:

- The postponement of something good and possible for the sake of something that could be better but is not currently possible.
- Reverse delegation—those responsible for a task transfer it to their managers.
- Imprecise decision-making ("analysis paralysis") because an algorithm for decision-making is lacking.
- Tasks declared as everyone's become no one's.
- False dependencies, wherein one task is linked to the completion of another when both can actually be undertaken simultaneously.

- Circular task concatenation ties, where A depends on B, B depends on C, and C depends on A, and thus one can never get out of this circular reasoning.
- Behaviors guided by informal decisions ("someone said that . . .") that have not come explicitly from any directive or collective decision-making body.

Directors must investigate these pathologies with the attitude of an epidemiologist, detect them through their early symptoms, and sever the contagion chain.

"Managers are the backbone of the Revolution," Che Guevara said. This concept is especially important for knowledge economy organizations, which depend on innovation and whose products and processes, precisely because they are innovative, frequently lack reference points to structure and evaluate them. The manager's work in any activity consists of setting objectives, establishing procedures (and ensuring compliance), distributing resources, assessing performance, and motivating people. Manager development is a selective and educational process. First, one must select people with high internal motivation, discipline, and communication skills, and few have all these qualities. Then one must train them, which includes technical development in their specific areas and basic preparation in economics, human resources, legality, and management techniques. And a lot of political training.

Managers must thoroughly understand the organizations where they will be working. Knowledge economy organizations exhibit an inverted pyramid. In the traditional economy, a head of a company may know more about its activities than a unit head, who in turn knows more than a worker. In the complex organizations of the knowledge economy, the scientist or technician at the base of a process knows more than the head of the process, who in turn knows more than the deputy director to whom they report. This has implications for management styles and methods. In these organizations, managers work to guarantee employees' excellence,

not their own. A research and production center is not a large laboratory headed by a general scientist. It is a different animal.

The structural units of these organizations can be very different from one another, and their technologies are very specific. Hence, operational decisions cannot come from above. Managers must have considerable leeway for decision-making. Top-down direction can be limited to using three tools: the approval of objectives, budget approval, and the approval of political education for managers. All others are operational decisions that must be left to the base managers, who must be evaluated according to the fulfillment of the objectives.

In knowledge economy organizations, everything depends on speed: how quickly we scale up production, meet demand, correct deviations, and develop new products. In complex biotech transactions, the only thing that truly protects our technology assets from competition is our ability to act faster. Hence, one of the main functions of managers is to set the pace at which things are done. Every decision must be evaluated, not only for its impact on costs but also for the likely impact on process speeds. Given the innovative nature of projects and processes, this speed generally has no reference points. The boss must have enough intuition to decide when it is possible to move faster and enough dedication to set an example. There is no worse tragedy in an organization than a tired or skeptical boss.

The experience of the biotechnological sector has also been a lesson in the enormous potential that socialism holds for constructing an economy based on knowledge. The particularities of the knowledge economy are an objective consequence of the development of productive forces, which leads to an ever-closer integration of science with the economy. But, in social systems, these particularities are expressed differently. Private property, the attempt to privatize knowledge, competition between companies, market laws, the speculation economy, the interaction with society guided only by solvent demand, and the exclusively economic motivation of workers do not constitute fertile ground for

organizations seeking to efficiently integrate scientific research, production, human capital development, and social impact.

Socialism's features—social property, collaboration between companies, absence of intellectual property barriers, linkages between companies and social programs (such as the health system), state prioritization of human capital development, long-term orientation, social commitment of the managers, and workers' motivation—are powerful levers. They explain the development of Cuban biotechnology. Our management processes must exploit and enhance these advantages.

CHAPTER 11

The Knowledge Economy and Socialism: An Opportunity for Development

In and of itself, the knowledge economy, as a technological phenomenon produced by science's growing impact on production, is not necessarily an opportunity for socioeconomic development. However, under socialism, it is. This is the most general idea around which the arguments of the preceding chapters converge. In recent decades, economic development and the transition to a knowledge economy have produced abundant literature, but it treats them separately. Few studies address both issues simultaneously.

The literature on the knowledge economy comes almost entirely from the North.[1] With the most powerful countries of the industrialized North being market-driven capitalist economies, it is no wonder that their literature treats the knowledge economy as a technological phenomenon, concentrating on new ways to generate value, thus avoiding the key issue of who appropriates the produced value. This way, an important part of the analysis is lost. Unsurprisingly, much of the literature on economic development comes from the Global South. There, the just aspiration for development remains a postponed task ever since the colonialist expansion of the sixteenth century relegated dozens of countries

to sources of raw materials and cheap labor and a captive market for continuous accumulation at the center.

Leftist thought on economic development is basically framed by three ideas:

1. The growing polarization of the world through a hitherto unstoppable process of wealth concentration and marginalization of people.
2. Economic underdevelopment is not a stage toward development but rather its other side. Both processes cause and condition each other.
3. The demise of neoliberalism as an economic development strategy.

Today, 150 underdeveloped countries represent 85 percent of humanity. In this population, there are 800 million undernourished people (15 percent of the world population) and 1.3 billion live in poverty. One-third of the world's adult population (950 million) is illiterate. At the wealthy pole, approximately forty countries comprising less than 20 percent of the world's population accumulate 86 percent of the planet's Gross Domestic Product and account for 82 percent of all exports.[2] An elite of fewer than 800 people accumulates an average of $3 billion each. Socioeconomic development indicators all paint the same picture: a huge and growing rift between rich and poor countries.[3] The trends of the world economy do not lead to the development of that poor 85 percent of humanity but rather to the deepening of underdevelopment. The idea that developing countries could follow (two hundred years later) the same path of industrialization as today's developed countries is definitely being abandoned, and it becomes evident that the true cause of underdevelopment is (and always was) the continuous extraction of the economic surplus generated by poor nations and its transfer to rich ones.

The two poles of development and underdevelopment exist because they produce one another. The exploitation of the periphery makes it possible to maintain growth and relative social peace

in the core countries, which "export" their contradictions. The recipe of neoliberal fundamentalism—deregulation, privatization, free flow of capital and goods (not of people), and the withdrawal of the state in favor of the market—has only aggravated the problem.

THE KNOWLEDGE ECONOMY AS AN INSTRUMENT OF EXCLUSION

In this polarized world, the transition to the knowledge economy begins in industrialized countries. For two hundred years, neoclassical economics recognized two factors of production: capital and labor. Knowledge (and education) was considered an exogenous factor, an "economic externality." In the twenty-first century economy, knowledge becomes a third factor of production, and economic growth becomes increasingly dependent on the accumulation of knowledge. In fact, scientific research is internalized by many companies as part of the value chain, which creates the need for an increasingly qualified and motivated workforce.

The world economy is transforming step by step in this direction. This is not a completed process, but this is its clear trend. The just aspiration for economic development can no longer be the attempt to reconstruct a past of standardized industrialization with a high consumption of natural resources and a low-skilled workforce. The challenge is to move forward, but toward the type of economy the world is heading to, not toward the past. And we must be careful with this confusion because it can be effectively utilized by the usual exploiters.

Is the increasing connection between science and the economy a new exclusionary threat for poor countries? Or does it have the potential for emancipation and development? It is both at the same time. Certainly, the threat is there. The North-South divide is even more evident in research and development data than in economic data, such as GDP per capita or share of world trade. The United States-Japan-Germany group has a percentage of the world population similar to Latin America's (8 percent). The contrast in

GDP per capita is 42 percent versus 7 percent, while it amounts to 47 percent versus 1.8 percent for investment in research and development and 53 percent versus 1.3 percent for the number of scientific authors.[4] It could be said that today's technological and scientific rift anticipates how wide tomorrow's economic rift could become if these trends are not reversed.

An estimated five million people worldwide are involved in scientific research. Of these, 72 percent reside in industrialized countries. More than 80 percent of all scientific publications and more than 90 percent of patents are generated between Europe, North America, and Japan. Likewise, 98 percent of the most cited scientific publications are generated in thirty-one countries. The remaining 2 percent is shared by the other 162 countries. The positive feedback between science and the economy progressively creates the conditions for an irreversible bifurcation of humanity. This process, just like the deterioration of the environment, is cumulative and may have a point of no return. By being integrated into the economy, science loses its erstwhile neutrality and can function as an instrument of accumulation, marginalization, and exploitation. Capitalism has created the mechanisms for this.

THE KNOWLEDGE ECONOMY AS A DEVELOPMENT OPPORTUNITY

However, by being integrated into the economy, science can also act as a force for liberation. The opportunities to open a path of knowledge-based economic development certainly exist, but not within the so-called market economy. The fundamental contradiction of capitalism is and has always been between the social character of production and the private character of appropriation. This contradiction becomes even deeper as the productive forces advance toward an increasing role of knowledge in production and services. Even within the developed capitalist nations, the attempt to privatize knowledge creates more transaction costs that slow the development of productive forces. But the problem must

be seen on a global scale since globalization, although existing since 1492 (and we Latin Americans know it well), makes it more evident that the real economy is the world economy.

However, mending the rift between the poor Global South and the rich North through the knowledge economy requires strengthening the ties between science and the economy within the developing world. This entails scientific-technical activity in Global South nations, promoting production and creating added value in these nations at the local and national level, or even better, through regional integration. Under capitalism, the short-term logic of the market operates in the opposite direction and closes the link between scientific research and production through the economies of the Northern nations.

The defense of the national character of development strategies does not mean an attempt (impossible in the twenty-first century) to undertake self-sufficient development that is disconnected from the world. Yet it is necessary to understand that although creating value in increasingly global flows of products and services is an economic fact, the distribution and use of the resources produced is a political fact, reflecting power relations within every society.

It is true that globalization, understood in the sense of the world market, has existed for a long time, as have technological innovations. But the degree of connection between globalization and technology is a relatively new phenomenon. This creates a positive feedback loop: technology enables economies of scale to produce for the world, and global-scale economic operations make it possible to finance the rising fixed costs of scientific research and quality systems. Like all positive feedback, this loop has a bifurcation point, from which it can function as a virtuous circle or as a vicious one. Technological development allows for large exports that finance more technological development (which generates a growth spiral), or technological backwardness translates into a lack of resources for investment in science and technology, which thwarts the possibility of large industrial projects. Human capital is thus lost because of disqualification or emigration.

This is the dilemma. The strategy of substitution industrialization to satisfy the domestic demand in the Global South, recommended by many economists in the 1960s, is no longer possible in the twenty-first century.[5] The mutual bond between technology and globalization exists; the issue is whether we can reverse its function as a perpetuator of underdevelopment and turn it into an engine to move forward. Only state intervention in socialism, as the institutionalized representation of all people and as an instrument for collective action, can reverse the process of widening inequalities that the knowledge economy itself amplifies.

The production of knowledge is an individual endeavor only in appearance. In actuality, it is a social process increasingly dependent on the environment of knowledge circulation that surrounds creative individuals. It is not a space of competition but of collaboration. It is not stimulated by any "invisible hand" of the market but by the highly visible hand of the state, which guarantees the redistribution of social resources and their preferential use for the cultural growth of all people, as well as the protection of development in the medium term. This is not only a problem of equity, although, in and of itself, equity would be enough of a moral justification for it. It is also an imperative of efficiency in economic development, which in the knowledge economy can only take off from an accumulation of human capital that takes years of conscious intervention to build. Years and resources, since the construction of human capital is a long-term investment, which in the short term competes with consumption and requires political power for its consistent and lasting implementation.

The demographic resources of the nations in the Global South, enhanced by education and the motivation generated by an inclusive social project, can be an enormous potential source of comparative advantage if we articulate their connections with the economy and remove the barriers built by capitalism. To do so, we must know how to read the national and global context in which these processes occur and undertake a consciously driven development strategy.

THE CONTINUITY OF THE CUBAN REVOLUTION IN THE KNOWLEDGE ECONOMY

Faced with the global problem of access to development in the knowledge economy, where do we Cubans find ourselves, and what is our balance of opportunities and dangers to enter the twenty-first century? After more than sixty years of fertile efforts to build a different society and of resistance to external economic aggression that has undoubtedly eroded our economic performance, we are at a special crossroads that exhibits particularities we must understand to guide our conscious action.

If we understand economic development not through the reductionism of the Gross Domestic Product but as a multifaceted process made up of the added value of production, the structure of the human resources of production, and the indicators of equity and social welfare, then it becomes evident that in Cuba we have a dissociation among these three components. We have a highly qualified workforce with very good indicators of social well-being (health, education, security), but which has not been able to proportionally deploy a large and high value-added productive apparatus. Other Global Global South nations show an inverse dissociation: high-value productions based on the abundance of primary natural resources (oil, minerals, large land extensions) but an inability to translate them into social indicators, equity, or the training of workers.

We Cubans have no other option than to use science and technology as the main lever for development. We do not have great natural resources nor a domestic demand that guarantees economies of scale in traditional industrial productions. We neither have a large population nor an age structure compatible with extensive economic growth based on primary products or traditional industries. The three essential markers for development—the growth in the added value of our production of goods and services, the continuity of the qualification of our workforce, and the continuous

improvement of the indicators of social well-being—must come from science and technology.

The good news is that we can do this. We have the human capital, the educational level, and the social cohesion generated by a project of equity and solidarity. We also have the socialist state at the head of the economy. Likewise, the Latin American regional context is evolving, not without difficulties, but with a clear trend toward integration. The opportunity is here, and we are responsible for making good use of it. And we must do this quickly because there are also risks. Some come from abroad, and others are internal. There are basically two threats from abroad. The first is that the U.S. economic war against Cuba will continue, affecting our economic performance to varying degrees. The hostility of those who benefit from the current world economic and political order toward those attempting different paths is something to be reckoned with. This is the price that we Cubans pay for our choice to build something new. The second threat in the foreign context comes from the large multinational corporations' control of the market for high-tech products, which shapes the global regulatory context to suit their interests. In the pharmaceutical sector, this effort to construct entry barriers (visible or subtle) to preserve monopolies is especially evident.

That is the world in which we Cubans must undertake the task of economic development based on knowledge. But there are also internal risks. The first is that we may lack the creativity to design the type of company and regulatory context that catalyze the continuous growth of the added value of our products and services. An essential component of this creativity is to find the optimal balance between the centralization of macroeconomic decisions—which guarantees the coherence of the companies' actions vis-à-vis the national strategies and the protection of the medium term—with the decentralization of the operational decisions that guarantee the capacity of companies to adapt to changing situations, as well as the continuous exploration (with its inevitable share of failures) of new opportunities. Such decentralization cannot be limited to the

internal functioning of companies but must extend to the companies' interactions with the outside world. This is the case because the bottlenecks are located here, in the entry of supplies and the export trade outlet. This entails another risk since these interactions occur within a capitalist environment with values and rules that differ from our view of marketing as corruption and flexibility as predation. Last, there is the risk associated with preparing our managers for the complexity of these tasks. It is this combination of opportunities and risks that generates in us an immense sense of responsibility.

Given that there are no examples to emulate, we must invent our own solutions to the challenges of economic development based on knowledge. They include:

- Continuous human capital training at rates higher than today's productive forces demand (what we have done since 1959).
- Maintaining the distinction between business management, which must be increasingly decentralized, and the ownership of the fundamental companies on which development depends, especially high-tech companies, which must remain in the hands of the state.
- Encouraging companies to invest in technological development and science, managing the balance between budgeted financing and the business funding of scientific research.
- Capturing the concept of the high technology company in redesigning the Cuban business system, based on our incipient experiences and the regulatory framework that stimulates its growth.
- Institutionalizing the process of emergence of new state companies that explore possible technological and economic discontinuities, accepting the risk component and the inevitable number of failed attempts that innovation entails.
- Reaping the advantages of planning for leading indicators and balances without turning planning into an impossible attempt to anticipate the future in all its details.

- Raising, even in the face of short-term economic pressures, the level of long-term state investment in science and technology, whose economic effect is hard to program and only becomes evident in hindsight.
- Strengthening the connections of our scientists and technologists with the world, absorbing knowledge and preserving our values.
- Addressing the migratory pressure on qualified personnel, a worldwide reality based on differentials in technological intensity between the economies of the North and the Global South and opportunistically stimulated by those who benefit from it.
- Designing the spaces and roles of the business system, the subset of high-tech companies, higher education centers, and the budgeted scientific institutions without subsuming one system into the other and protecting the specificities of each one.
- Taking advantage of the new possibilities opening up in the economic integration of Latin America and contributing to this process while preserving our approaches from our historical trajectory.

The Cuban people, with that shrewd popular intuition that often surprises the most sophisticated intellectuals, know that economic development will not come from small-scale property (although we must make room for it) nor from foreign investment (although we do require it at certain times and in given sectors). Only the socialist state company can direct the knowledge economy with efficiency and perspective. The more our economy is based on science and high technology, the more socialist it will be. This guarantees the effective distribution of social resources as a function of everyone's quality of life, including those born tomorrow. Young Cubans cannot allow themselves to be confused by market naiveté. They must understand that for the Cubans of today and tomorrow, the dilemma remains the same one that Rosa Luxemburg identified in 1915: "socialism or barbarism."[6]

CHAPTER 12

The Knowledge Economy and Socialism: Cuban Questions

The first edition of this book was discussed by the general public in open presentations, university students from various schools, workers from scientific institutions, government and Communist Party cadres, and company directors, among others. There also have been discussions with stakeholders from other countries, but in this chapter, I will focus on points that Cubans raised. We Cubans have lived, and will continue to live, a unique revolutionary historical experience. The depth of our social processes and their changes, and the major participation of the people in them, has created a special corpus of knowledge in today's generations of Cubans. We understand what we have done well and what we have done wrong, our history and our collective aspirations. This shared knowledge allows us to examine our certainties and uncertainties.

REAFFIRMATION: WHAT NO ONE QUESTIONED

The questions we heard focused mainly on three issues: the state company as the main form of the economy; the national context (especially the factors that promote or inhibit economic

development); and the external context, with its opportunities and threats. I have organized responses to fifteen questions related to these issues. I do not have the answers to all of them. At best, I have intuitions derived from my experience and different types of evidence. Let us also remember that its contents must be viewed from the perspective of the biotechnology sector in its transition from an academic context to an entrepreneurial one.

Before delving into the answers, it is important to highlight what people did not ask, as that is the area of certainties, which must be reinforced before entering the realm of uncertainty. No one questioned the significance of the issues. Our historical experience has been exemplary in transforming scarce material resources into human capital and social development. But it has not been excellent in the opposite direction, that is, in making social development generate new economic development. That is the main challenge to the collective creativity of Cubans and their institutions. No one questioned the feasibility of an economic development strategy based on knowledge or the advantages of socialism.

Moreover, we are aware that this is the only possible strategy. We do not have, like China, a large domestic demand for goods and services that powers industrial growth. Nor do we have, like Argentina, huge amounts of fertile land to guarantee food self-sufficiency and agricultural exports. Unlike Venezuela, for example, we do not have the natural resources the world demands. Our essential insertion in the globalized world economy must be articulated based on goods and services with high added value or value created by knowledge. Thus, the questions did not focus on our limitations or the feasibility of achieving our goals based on the material and cultural foundations built by the Revolution. Instead, they were about how we achieve them.

THE SOCIALIST COMPANY IN THE KNOWLEDGE ECONOMY

1. What kind of company does the knowledge economy require?
Many questions and comments referred in one way or another to

the operation of state companies. The company connects human capital and the economy. Therefore, almost everything about our economic strategy depends on it. It is the main space for creativity in the economic system being designed in Cuba.

Even in developed capitalist countries, the proportion of non-salaried workers and the proportion of domestic production they create do not exceed 10 percent. The remaining 90 percent work for companies that pay them salaries.[1] The ownership of these companies is mostly private in capitalism and public in socialism, but the organizational phenomenon is similar and depends on the development of the productive forces, not on the ownership structure.

In various debates about the operation of our companies, some colleagues start from the unstated (and perhaps unconscious) assumption that, in Cuba, what a company must do is well-known, and what has been lacking is regulation, rigor, and discipline. This is wrong, or at least incomplete. For our socialist companies to succeed in an open and competitive economy based on the valorization of human capital in the context of socialism but without large internal markets and natural resources, we must embark on a new and untrodden path unlike that of European socialism. This is the reason for the frequent questions about the type of company we need in our specific context and moment. We must consider this first, and only then can we start analyzing the internal procedures and regulations that should govern business life.

This book attempts to systematize what has been learned from the biotechnology sector in Cuba. My approach has the advantage of starting from a concrete experience but also the disadvantage that it is, like all experiences, partial. Thus, without pretending to offer general answers about the kind of company we need for our economic model, I can describe the type of company that emerged from the biotechnology experience.

The knowledge economy pertains to all companies to varying degrees. But, in some, the permanent development of new products and services based on science and innovation is the main

component of their economic activity. These are the high-technology companies described in the preceding chapters. They should be treated differently to guarantee their growth and proliferation. But in all companies, whatever their technological level, it is necessary to create absorptive capacity for new technologies, many of which will gradually become cutting-edge technologies.

First, I will highlight the company's essential features in the knowledge economy so that they are not lost within the multiple aspects, processes, and regulations of business life. All the decisions we make about the operations of this company must be assessed according to whether they contribute to reinforcing these features. Based on five features, I will sketch a portrait of the companies we want.

They must be state-owned. Our perspective is that private ownership of the means of production represents the past, just as slavery does. The future is the property for all, from which all benefit. Although today we are still somewhere between the past and that future, we cannot forget where we want to go and must act accordingly. The economic and political catastrophe of the European socialist experience arose from forgetting that principle. The state company is the economic base of social justice, and justice is the social base for the defense of national sovereignty, especially in Cuba.

There also is a technical reason for the preeminence of the state company. When social revolutions occur in countries with little economic development, the goal of redistributing wealth is necessary but insufficient, for there is little wealth to redistribute. Once the bourgeoisie is expropriated, the central objective becomes economic and social development. Both require resources. Where will they come from? The state taxes the economic actors of nonstate property, but these revenues are insufficient because of the low level of economic development. In addition to taxes, the state obtains most of its profits from state companies since it is not only the tax authority but also owns the companies.

As we shall see, ownership need not be synonymous with direct

management. But there can be no concessions regarding the state character of property. We do not want to change that. Nor do we need to: technological development has tended to separate ownership and management, even in developed capitalist economies. Social property is a political commitment; management forms are a technical phenomenon.

The state company must have incentives to move forward in the value chain, introducing higher-value-added products and services: We cannot generate development through manufacturing companies that have abundant and cheap labor but whose production has low added value. This was the initial strategy in various Asian countries, but it cannot be ours. We do not have an abundant workforce, nor is our workforce cheap because our economy must fund its social achievements. Today, our companies do not have enough incentives to move toward high-value products and services. Introducing new products generates value in the medium term, but in the short term, it demands investment and involves uncertainty. Our regulatory context puts a lot of pressure on companies to increase profitability in the short term and does not tolerate uncertainty. These are concrete disincentives for the development of companies. Production and services of high added value probably will originate in the entities called high-technology companies. This is what the experience of the biotechnology sector suggests. This type of company usually has a high fixed cost, given its technological complexity, the intensity of business scientific research, the continuous improvement of quality systems, and the cost of skilled labor. This leads us to the third feature of the company we need.

Companies must be export-oriented: Fixed costs must be internalized in large commercial operations, which are not profitable given Cuba's low domestic demand. The company will operate in an open economy, where the foreign market will increasingly determine feasibility. Low domestic demand does not attract development. The external market might not dominate Cuban business, but its role will be larger with greater technological complexity of production.

We have low-tech and low-added-value companies serving certain domestic demand sectors. We may be able to export primary products with low added value. But a high-tech company operating solely for domestic demand will simply not survive. So, parallel to their technological development, our companies must be brought closer to the external market. In and of itself, developing new technology is not a source of economic value. The source of value is identifying market needs (in this case, the external market) and concentrating efforts there. If the company does not interact with external demand, it will be partly isolated from market signals and will not be in control of the fundamental levers that determine its efficiency.

Here, our reasoning leads us to another challenge, typical of the Cuban context, which is another reason we cannot copy anyone. The first socialist economy arose in the USSR, a large country with many natural resources and a large internal market. Then, the socialist countries of Eastern Europe entered COMECON.[2] Their dependence on exports was lower. In Cuba, we face the challenge of an internal economy that is not captive to market laws but obtains its resources from interacting with an external economy ruled by those laws.

Management must be autonomous: Managerial autonomy is the dialectical complement of state property. The state is related to the company as owner, on behalf of the people, but not necessarily as administrator. Ownership confers responsibility for strategic decisions, not operational ones. Obtaining an important part of the profits after taxes and designating our main executives is another point on which we will not make concessions.

Management autonomy implies the ability to explore alternative products and markets, which includes tolerance for and protection against possible failures. Moving forward in the value chain entails exploring new products, services, and markets whose profitability is unknown. This implies analytical capacity and trial-and-error processes that consume time and money. The development process generates economic waste, and we must accept that. For the

company to behave like this, it is necessary to create incentives and release brakes. The system must have a tolerance margin for failed explorations. The control system we have established for companies does not have this margin. It presupposes a high capacity for predicting the future and operating within a safe space. Concrete ways to allow the company to manage uncertainty and explore alternatives must be studied, and some recent decisions we have made go in this direction. Understandably, an economy that lives under external pressures would develop a risk-intolerant system. But it should be possible to have cautious and gradual behavior at the macroeconomic level while implementing bolder behaviors in certain companies at the micro level. The regulatory system we impose on companies cannot be limited to rewarding efficiency but must also reward economic growth. The system we currently have is biased toward incentivizing efficiency.

The state company must have the ability to invest: This is a controversial issue since the realities of the Special Period and the U.S. economic war against Cuba have limited our investment capacity, and investment is the chief lever for growth. The issue under debate is not whether investments are needed, which is obvious. The challenge is to create the capacity to make investment decisions at the company level.

We need a larger proportion of our income to be invested (and not go toward consumption), thus increasing capital formation. When a company has profits to reinvest (say 25 percent) and does not do so, and those profits are captured at the central level, investment capacity is diluted by 13 percent of the country's general investment rate, diverting a large part toward consumption. A direct consequence of allowing companies greater investment capacity is the need to gain greater access to bank credit. Some companies will require access channels to external bank credits or partnerships with foreign direct investment. It will be necessary to define which companies and the Cuban banking system's intermediation and facilitation roles.

Finance is the lubricant of the economy. Development financed

with past earnings of companies will necessarily be slow, and it is not the world's common tendency, even in solid and profitable companies. Our current control systems put more pressure on managing through accounting and less on designing effective financial strategies to ensure growth. This must also be balanced to achieve accelerated development.

2. How can central planning be reconciled with the uncertainty and exploration typical of high-tech companies?

This is a main theme in the world debate on economic problems and also in Cuba. During the four decades (1950–1990) when academics debated the economic performance of capitalist and socialist countries, one of the most widely used classifications was that of "centrally planned economies" versus "market economies." This issue was at the heart of the debate. And one of the errors that led to the dissolution of the USSR was its abandonment of planning. Little by little, the critique of planning deficiencies and the need to improve it was replaced by the critique of the planning concept itself, and thus emerged the supposed need to replace it with market mechanisms.[3]

The controversy over planning versus the market is not only a technical debate about how to better organize the economy. It also is related to moral and political values. When production and investment exclusively respond to market signals, they end up satisfying the needs of the wealthy (the so-called effective demand), and a spiral of expansion of social inequalities is set in motion.[4] The construction of socialism implies a progressive transition from the market toward planning as the main way of managing the economy. It is essential to insist on this concept because we need to learn how to criticize a type of planning, not the concept of planning itself. Socialist planning is not just a technical process but also reflects concepts and values about a society's use of its productive capacities, the goods and services we seek to produce, and the distribution of production. We are not going to repeat the mistake that others have already made. The first of the Economic Policy Guidelines approved at the Communist Party Sixth Congress states,

"The socialist planning system will continue to be the main path for the direction of the national economy. . . ." But it also states that "[the system] must be transformed in its methodological, organizational, and control aspects." And, ". . . it will take into account the market, influencing it and considering its characteristics."[5] There always will be planning in the modern economy. The isolation of the producers that interact in the market is unthinkable in the technological context of the twenty-first century. If economic decisions are not in the hands of the state, then they would be in the hands of an oligarchy with no responsibility vis-à-vis the people or a long-term vision.

Planning in the twenty-first century cannot be the same as in the 1960s, given the different productive forces. Two phenomena of the past fifty years have changed everything: the accelerated development of new technologies and the globalization of the economy. Technological development implies rapid changes in products and how they are produced. Globalization implies large-scale production and supply and distribution chains beyond national borders. Both reduce the ability to predict and show that what a company needs is not so much the ability to predict the future but adapt to various possible futures. We can identify problems linked with information theories and complex systems without theorizing or offering abstractions.

Throughout the twentieth century, economic systems greatly increased their interdependency and the speed at which they experienced changes. Mathematicians who study complexity theory know that the greater the number of components in a system, the greater the non-linear interactions among them. This makes it impossible to predict the system's general behavior from its components' properties, even if knowing the laws that govern the interaction between them. Uncertainty is a property of the universe, not an artifact of our limited ability to know and reason. The concepts and procedures of socialist planning that we assimilated were written when technologies were more stable and essentially served national markets. And they were fundamentally written

in the Soviet Union when it had to opt for a model of internal economic self-sufficiency, given its isolation by hostile capitalist powers.

In addition to planning the productive supply, a large country like the USSR, with abundant natural resources, could plan demand. The model worked, at least for a while. Data show that, after the enormous feat of the Great Patriotic War and the rapid recovery from the material destruction of the war, in the two decades from 1950 to 1970, the GDP of the USSR grew by more than 5 percent per year, a rate higher than that in the United States. And that was achieved with a centrally planned economy.[6] But that same form of planning ceased to be functional in the USSR during the 1970s (an issue that we will not discuss in detail here), and it will not be functional in the twenty-first century for a small country like Cuba, whose development increasingly depends on external demand, which is not very plannable.

Why does this issue come up so strongly when talking about the knowledge economy and the experience of the Scientific Pole? It is because the Cuban pharmaceutical sector exhibits characteristics that are most similar to this century's technology-based and globalized economy. In this sector, we have products that are frequently replaced, comparative advantages based on innovation, and greater dependence on the ability to insert our production into the global flows of products and knowledge. Here the limitations and dangers of an excessively detailed and centralized planning model are more clearly seen, and it becomes evident that the proliferation of explicit and frequently contradictory regulations is a source of disorder.

With its anti-social effects, the market is less efficient in guaranteeing the development of a knowledge economy. Socialist planning must be compatible with economic sectors characterized by frequent changes in supply (e.g., new products and technologies derived from innovation), external demand, uncertainty in forecasts, and decisions where risk is the rule and not the exception. How will we do this? There are no theoretical solutions to

this challenge, and we must experiment creatively and responsibly. Perhaps we will need to manage uncertainty with non-deterministic planning schemes, focused on aggregate indicators more than on the internal details of each process, with more financial indicators and fewer material ones, which include probability ranges rather than fixed goals.

3. Can the lessons learned be extrapolated to other companies that are not necessarily high-tech?

I will give an equivocal answer, "yes" on a conceptual level and in the medium term, but "not yet" on the measures we can adopt in all companies. The five features of high-technology companies discussed previously need not be exclusive to them. State property, high value-added products, export orientation, management autonomy, and investment capacity should be characteristics of all companies. The typical features of the high-tech company are the internalization of scientific research within business costs, the rapid replacement of products and technologies by new ones, and negotiations based on intangible assets. These traits can be extended to other companies and sectors. The Cuban socialist company must evolve in that direction. But we must proceed gradually. We cannot confuse our intentions with reality and must recognize that the path is not without risk.

Entrepreneurial autonomy can generate waste and even corruption. Direct interaction with external markets can weaken state control over the economy and hinder synergies among industrial sectors. The irresponsible use of financial intermediation can put companies into debt. We do not have many managers specializing in operating companies with these attributes. The speed at which we implement these policies must start from an understanding of these risks and the creation of devices to mitigate them.

Redesigning the business system and its regulatory context so that it promotes state-owned companies and autonomous operation, exports, the permanent development of new products and services, market exploration, and the efficient use of financial intermediation cannot be achieved by decree, nor in a single year.

On the other hand, it is also essential to compare the risks of each decision with the implicit risks of not making them. In addition, we cannot pretend to alleviate the shortcomings of our companies by transferring business functions to the state. What we regulate must always resemble the future, and it is essential to share a vision of what that business future will be like, even if we cannot immediately build it.

In some sectors, such as BIOCUBAFARMA, the conditions exist to advance faster, not because workers and managers are more capable or hard-working than others, but because of decades of experience. The pharmaceutical sector is not exempt from errors, but it exhibits a creative balance, management autonomy, the internalization of science within companies, constant replacement of leading products with new ones, and permanent reinvestment. This sector is export-oriented, directly interacting with foreign markets and negotiating intangibles. We can now create a regulatory context for high-technology companies based on that experience.

One of the best contributions our nascent high-technology companies can make to the economic model beyond their income is to serve as a field of experimentation for deploying the attributes that should gradually permeate more spaces in our business system. High-technology companies' technology requires greater autonomy in decision-making, and faster movement toward high-value-added products, imposes an economic cycle that culminates in exports rather than in internal demand, and requires permanent reinvestment and financial strategies. This company also has a greater density of highly qualified human resources with lower risks.

The economy, like genetics or the immune system, does not evolve in an instructive way, implementing strategies that can be predicted to work, but rather has a high component of evolution by adaptive selection, based on an enormous diversity of variations, many of them random, whereby those best adapted to the environment are selected and fixed to transmit their characters.

We already have the first "mutants" in some companies, which we must now cultivate by creating appropriate milieus for them. The regulatory context of the Cuban business system must be that suitable environment for the exploration of diverse alternatives, as well as the selection, consolidation, and transmission of the most useful ones.

4. Is there room for non-state forms of management in high-technology companies?

At the risk of sounding dogmatic, which I prefer to sounding ambiguous, I will answer this question with a resounding "no." In our conditions, such a space does not exist, or at least it is very small and irrelevant. There are ideological reasons and technical reasons for this.

Our economy must move as quickly as possible toward the high-tech zone, confronting with high-value products the limitations derived from our lack of natural resources and our demographic evolution, and taking advantage of the human capital we have developed in fifty years of Revolution. Fidel Castro said in 1993 that "science, and the products of science, must one day occupy the first place in the national economy." If that is the main direction of our evolution, and if we affirm in the guidelines that "the state company is the main form of the national economy," then the state company must lead this transformation. The high-technology company must operate with high productivity and low material costs. The low cost per weight/dollar [peso] is the return of state investment to form human capital. It belongs to those who invested, that is, to the Cuban people, represented by the state.

In addition to these ethical reasons, which in my view are more than sufficient, there also are technical reasons. Even if efficient, non-state management is almost always driven by immediate gain and almost always leads to a short-term approach. When it comes to undertaking something new, such as the expansion of the high-tech sector, we must study the path taken by others, but we must also have a critical attitude towards what we read and know how to read between the lines. The high-tech sector in the United States,

exemplified by informatics and biotechnology, did not emerge as the prerogative of established private companies that invested their profits.

In its early stage, it was nourished from two different sources. First, from the availability of risk capital in the U.S. financial surpluses, given its dominant place in the world economy. Yet, even with such an available surplus, which moves across sectors in the stock market, it was necessary to "invent," in 1970, another regulatory context. This was the alternative NASDAQ stock market, given the conventional stock market did not contribute the "patient capital" needed to incubate companies that would take several years to transition to profitability.[7] Approximately 3,400 companies are listed on NASDAQ today.

Second, the companies directly connected to science that emerged in this particular financial context were nourished by the results of state-funded scientific research. The internet, the basic genetic engineering technologies, and later the mapping of the human genome all arose from projects financed with public funds allocated by the government. Their willingness to invest their profits in long-term and uncertain return projects is exactly the opposite of the usual attitude of private companies, always in search of short-term returns. There are exceptions, of course, in large companies in countries with vast resources, but even they are not many. This has not occurred in the private sector in the Global South countries and is unlikely to happen in the foreseeable future.

Efficiency in allocating resources to the moment's needs is the (questionable) virtue that neoclassical economic theory claims for the market. But this does not work for the high-technology economy, much less in underdeveloped countries. The knowledge economy requires an entrepreneurial state. The socialist state company can mend the rift between the decoupled attitude of the economic return, typical of the budgeted sector, and the short-term and cautious attitude typical of the classical business sector. This is one of the great advantages of socialism; our task is to enhance it.

5. ***How does leadership work in a high-tech company?***

There are many books about business leadership; they run the gamut from deep thinking to superficiality.[8] The necessarily brief answer to this question cannot cover all the subject's nuances. I will focus on those statements derived from experience, which we know will cause controversy or at least surprise.

High-tech companies cannot be managed solely through procedures. Procedures, by definition, encompass what is known to work, and these companies move in the realm of the unknown. Naturally, we must implement certain administrative procedures, but in high-tech companies, the objectives are much more important than the procedures. The latter are adjusted according to the objectives. In these companies discipline is required for success but is not sufficient. What guarantees success is the motivation of the workers and managers and the formulation of motivational, bold, and feasible objectives. Discipline is not synonymous with obedience or with compliance with the rules. Discipline is an ethic of constant commitment to collective objectives and coherence, even if it involves risks. People are guided by persuasion, motivation, example, advice, and transparency. The constant issuance of orders, which must be given when necessary, is often a symptom of the inability to persuade and motivate.

The knowledge pyramid is inverted in these companies. Subordinate specialists know more than their managers about specific subjects, and managers know more than their superiors. The leader is not the one who knows the most but the one who motivates people so that they can exercise their knowledge and abilities.

In this type of company, academic thinking (a generator of creative ideas) and pragmatic thinking (a source of solutions that can be implemented concretely) coexist. People who demonstrate these different approaches are often found in different organizations. In high-tech companies, they coexist under the same roof. The leader must be able to move between the two extremes without favoring either. They must also combine the strengths of both

approaches, although there is always a risk of combining their flaws instead.

Money is not the workers' primary motivation. Of course, wages are important, and we must fight to ensure that workers earn the best possible wage. But we cannot confuse the means with the ends: earning a good salary is the means for knowledge economy workers to have a decent material life so they can concentrate on the real sources of motivation: participation in important projects, overcoming challenges, intellectual growth, and a transcendent purpose to their everyday lives. The manager must know how to communicate this every day and in a thousand ways. Obviously, not all people want to work in such an environment. Many would prefer to work in other contexts with different values. But motivated people working toward bold goals (attained through challenges and uncertainties) exist, and they are not few. The recurrence of this question reflects the understanding that these companies need leaders, not just managers. And there is another very important characteristic: leadership is not about personal brilliance or the exercise of power. Authority comes from the ability to get things done properly within a structure of distributed power.

Creating spaces for direct and open debate with workers and devoting time to these exchanges is essential. Leadership is the ability to guide informed workers, and no authority is solid if it is based on the monopoly of information. Leadership also means creating spaces for workers' participation in decision-making and transparently discussing the complexities of every decision. We must also understand that the most important leadership traits change over time. The type of manager needed to guide a small, nascent company is not the same as that required to lead a mature company with established procedures and economic cycles of supply, production, and sales, which are known to work and are expected to be stable for some time. We must identify when the time has come to replace managers, not because they have changed and become less capable, but because the firm now needs a leader with a different set of capabilities.

6. Is there an export strategy for biotechnological services based on the knowledge accumulated over thirty years?

I do not know if such a strategy has been offered, but I don't think we should. The reason is the value chain. The labor power of a qualified scientist has a certain value. The institutionalized capacity to provide a service with a given know-how embodies more value, but the design and implementation of a project have even more, and the maximum value is obtained when the innovative product is commercialized. In principle, any of the links in the chain is "tradable" and can generate an economic return. But our task is to move forward in that value chain. My analysis pertains to companies that can generate and market tangible products, such as biotechnology, since there are other sectors where the service is the product. But in an industry that must generate material production, exporting biotechnological services for external business clients that develop their products means moving backward in the value chain.

Obviously, we must be open to any opportunity. We are frequently engaged in many projects, and our limited resources force us to choose only a few to develop while negotiating the others to recover at least part of the invested value. If we cannot realize and trade a product, the project must be negotiated before arriving at the product. And if we do not manage to do this, the next step is to export services, which is equivalent to hiring a qualified workforce. Here, the returns on past social investments are smaller and perhaps never recovered. This can be a withdrawal strategy during certain conjunctures, but it should never become a central component of our development.

7. How can intangibles be accounted for in the knowledge economy under socialism?

First, let me state that the valorization of intangible assets is a complicated issue, not only under socialism. Capitalism has tried to address it through stock market speculation, which has been a source of many problems. The negotiation over intangible assets (a patent, a trademark, the commercial rights of a product being

developed, among others) is one of the distinctive features of the high-tech company. The impact of knowledge on the economic cycle is so direct that knowledge itself becomes the object of negotiation, in addition to the product. In the Scientific Pole, several institutions have gained experience in the negotiation of intangibles. In its early years, the Center for Molecular Immunology had moments when the negotiation of intangibles was its main income source before the products we currently export were mature. This is a regular feature of high-technology companies in their founding stages. During the 1990s, alliances with pharmaceutical companies, whereby they essentially paid for the intangibles, represented 45 percent of the income of the U.S. biotechnology sector, and there were years when this figure exceeded 70 percent.[9]

However, these negotiations are very difficult to conduct, and extant methodologies are of little help. The classic method to calculate the value of a project or a patent is to estimate over time the current expenses and the investments necessary for an intangible to generate a marketable product. We must then estimate the profits that will be obtained from that moment, and recalculate both expenses and income, according to the value of money over time at a certain discount rate (which must always be higher than the bank interest, since otherwise the buyer leaves their money in the bank and does not invest it). This generates a net present value, a rate of return, and a recovery time. This elegant exercise must be done all the time, but it rarely influences negotiations. The reason is that all these figures, which already contain uncertainties, must be multiplied by a risk coefficient (which considers the probability that nothing marketable will come out of a project), and nobody knows what its value should be. This is where intuition and references to similar projects come into play.

For example, a similar calculation is made in an oil prospection negotiation. But in this case, based on more than a century of world experience in that industry, the probability that there is oil in a given place and its commercial value can be reasonably estimated based on geological or other data. At the opposite pole,

what is the probability that a new antibody, or a specific nanoparticle, will have an antitumor effect in humans? How large will that effect be, and, depending on that, what will be the market penetration and the price margin that it achieves? The answer is different for each product, and there are very few benchmarks to give one. This is why trying to record the value of an intangible in books, which is linked to a potential product that does not yet exist, is futile. However, estimating how much we have spent to get there can and should be done. Yet this shows the cost of the intangible, not its value. We will not know its value until it is negotiated.

What solutions are available? Not to negotiate would be to bury our heads in the sand, like the ostrich. We will always have more negotiable projects than marketable, mature products because the product maturation process is a pyramid wider at the base than at the tip. It is good that this is the case since it means exploring more alternatives, financing product exploration by negotiating intangibles, and selecting only the best ones to advance at our cost. We must permanently study this issue and build experience during negotiations. Much tacit knowledge is involved in this, which is acquired on a case-by-case basis.

Patents protect our products for twenty years. In the first years, we must decide if we will undertake product development ourselves, so we must rapidly make the necessary investments. Alternatively, we could negotiate about the product in its early stages and, in that case, rapidly undertake the necessary negotiations. Note that the word "rapidly" appears in both alternatives. Time is not irrelevant in high-tech industries, and unused resources—patents whose expiration time advances, products or technologies that are not developed, or investments that are not put to use—have negative productivity.

We first negotiated intangibles in our biotechnology sector in 1994. Many more negotiations came after that. In the following decades, a group of specialists acquired some experience. In 2004, we negotiated one of our cancer vaccines with a well-known foreign company. The agreement included payment for intangibles

even before the project began. In media interviews, the executive director of that company was asked why the company had paid such a figure and how it was calculated. He replied, ""The Cubans had done their homework."

8. ***How can a legal framework facilitate the expansion of the knowledge economy?***

The development of a legal context following our guidelines is occurring in Cuba. Some of the legal gaps we might identify in this debate may already be resolved when this book is published. I will focus on what is permanent. The legal context that regulates the behavior of companies is of utmost importance. Regulations can facilitate or inhibit the socioeconomic development processes that we undertake. They must capture the best experiences and the necessary balances at each moment, between control, which, when excessive, generates innovation paralysis and stifles development, and the expansion of business attributes, which, if excessive, opens the door to squandering, corruption, and the widening of social inequalities.

A regulatory framework contains the legal expression of the values that guide human societies. It must be sufficiently flexible so that companies can explore options and even make mistakes and rectify them. At the same time, it must provide controls to avoid the expansion of social inequalities. It must find the balance between equity and growth. The complexity of these decisions lies in the optimal balance between flexibility and control, which changes over time and is also different across business sectors based on the level of technological development of the productive forces. The more complex the technologies and the business schemes derived from them, the more infertile the attempt to micromanage companies at the level of their components and elementary operations. Several countries, including China, have specific regulations for high-technology companies. We must create our own, tailored to our reality and objectives.

In moving towards a knowledge economy, companies must monitor and direct their performance through aggregate metrics.

The greater autonomy in management demanded by our entrepreneurs, which the guidelines establish, does not consist in the absence of regulations. Wisdom lies in achieving the opposite: most of the procedures that companies need for what they can and cannot do are in the text of the law and not in procedures. This entails strengthening a legal culture, where much is still to be learned. It entails in companies the discipline to abide by the obligations and attributions the law grants them. But it also entails in the bodies that manage the regulatory framework not regulating beyond the law or imposing regulations on particular matters that distort the attributions and responsibilities that we must give to companies, as defined in the guidelines approved by the Sixth Congress of the Cuban Communist Party.

The legal context we build also must establish procedures for creating and dissolving a state-owned company. Some companies will require new opportunities. There will also be companies that prove unfeasible in the new context. At the same time, and as a counterpart to the required protection measures when a company has difficulties, it will be necessary to have a bankruptcy law or its equivalent, which orders the dissolution process if the company's unfeasibility is structural and permanent. These bankruptcy laws tend to be different cross-nationally, and their restrictive or risk-tolerant nature has had a concrete impact on the development of high-tech sectors. Once again, there is no universally valid recipe for all countries, all sectors of the economy, or all times. It is essential to construct a legal framework appropriate for our development.

In founding the Scientific Pole, the State Council coordinated its emerging institutions. This created an umbrella of legal protection that allowed them to explore alternatives, endure difficult times, and grow. These centers would later become high-technology companies. (We owe this brilliant strategy to the historical leader of the Revolution, Fidel Castro.) But the time has come to crystallize our experiences within a legal framework that catalyzes development.

9. What is the role of Cuban universities in the economic model we are designing?

This question came up in every discussion. This indicates the topic's importance and that the concerns and anxieties of the participants were not easily satisfied. The term "science" has been used in different ways. Here I will use it in the sense of a structured human activity aimed at producing new and generalizable knowledge, establishing regular associations between phenomena, and discovering causal relationships. In this sense, any debate on science must be preceded by an act of humility. Science is not the only intelligent activity of humankind. Culture goes further; it includes science but goes beyond it. Let us thus focus on that structured, empirical, and generalizable science, which has been a determinant of economic development in the last 150 years.

At the beginning of the twentieth century, only a few thousand professional scientists were dedicated to creating knowledge. Toward the end of the century, the number of scientists and engineers involved in research and experimental development worldwide was estimated at five million, a large part of them in universities.[10] In 2007, the figure was estimated at seven million.[11] Universities influence economic development in two ways: as creators of human capital (qualified people who later work in any budgeted or business sector of the economy) and as direct protagonists of scientific research, development, and innovation in priority sectors. I will not address the university's role as a creator of human capital. Other colleagues have done it much better.[12] Suffice it to highlight that the knowledge economy is precisely that, economy, and not just knowledge. That is, we need competent and creative people in all segments of the economic knowledge cycle: scientists and technicians, economists, business experts, lawyers, managers, social scientists, and others.

And we need cross-pollination across disciplines since development does not come simply from juxtaposing specialties. The recombination of knowledge must be built, and sometimes it is an uphill battle. In all professions, as we enter the knowledge

economy, the conceptual thinking capacity of specialists becomes more relevant, even if they do not work directly in scientific research. Let us thus examine this second role of the university as a direct protagonist of research and development. Today, the issue of university science in Cuba is even more important than when the first edition of this book was prepared. Our particular challenge is to foster economic development and expand social development. This demands scientific development and the connection of science with the economy. A system of science, technology, and innovation is precisely that: a social device aimed at the organized creation of new knowledge, the critical assimilation of knowledge created in other parts of the world, and its effective connection with the production of goods and services. Or, as the economists would say, "the enlarged reproduction of material life."

Universities are at the center of that system, and increasingly so. In 2012, the Scientific Pole merged with the pharmaceutical industry to create the business organization BIOCUBAFARMA. The Scientific Pole is now a group of companies. This was the correct decision and an expression of development. This emergence of new companies gestated in scientific centers should be repeated. However, non-entrepreneurial research is now largely, though not exclusively, in the hands of higher education centers. Until the nineteenth century, the organized creation of knowledge was an almost exclusive role of science academies and universities. Companies would later apply this knowledge to the economy, sometimes much later. In the twentieth century, cutting-edge technology companies began to directly finance scientific research and even internalize research in companies. This phenomenon grew in the industrialized world, and today it is estimated that companies contribute 70 percent of expenditures on research and development (70.3 percent in the United States and 71.7 percent in China).[13]

This global landscape of financing and implementing science has generated the false notion that all science is transferred to the business world and that scientific decisions will be increasingly guided by economic objectives (and, in capitalist countries, by

the market). This extrapolation has transformed universities into companies, mainly in the United States.[14] The influence of neoliberal ideology is easy to identify.

The truth is that scientific research and radical innovations, and not incremental improvements, are increasingly being identified as an area of market failure. These great innovations are often generated outside the business world. The dilemma between business science and budgeted science is a false one. We need both because they have different roles. The innovation economy is highly dependent on prior investment in enabling science, which must be made independently of any considerations of economic returns. The economic relevance of government investment in science is only seen in hindsight. In the Cuban experience, the essential technological frameworks and integrations from which the results of the Genetic Engineering Center and the Immunoassay Center were later derived arose from the National Center for Scientific Research (NCSR), then an organization of higher education. Likewise, the scientific bases of the Molecular Immunology Center arose from the Institute of Oncology, an institution of the budgeted sector. The Cuban vaccine against *Haemophilus influenzae* was created at a university. Then, the research-production centers converted these results into products and broadened the science that supports them. But we cannot confuse the harvest with the sowing, and we must keep sowing.

When this chapter was written (August 2014), Cuba's science, technology, and innovation system was being analyzed and redesigned. The Special Period and the reinforcement of the U.S. blockade left wounds and scars. And it damaged our science, technology, and innovation system. This is evidenced by data on investment in science, the number of scientists and institutions, and the production of publications and patents, among other indicators, which were once well above the Ibero-American average. Data even show the deterioration of our most precious capital, human capital.[15] As many revolutionaries have argued, the truth is revolutionary.

But the foundations for recovering and a new departure also are standing. We can no longer act as we did in the 1970s and 1980s, when, based on integration with the European socialist countries, we entered the scientific-technical programs of those nations. We will have to follow our own strategy. As President Raúl Castro stated in the 2014 National Assembly, "We are not going to copy anyone; doing so caused us a lot of problems because we also often copied badly . . . although we do not ignore the experiences of others and we learn from them, including the positive ones of the capitalists." This warning is especially relevant vis-à-vis the role of universities in our economic model because we possess a very special combination of risks and opportunities.

On the risk side, we have the financial resources limitation, the deterioration of facilities because of the lack of investment during the Special Period, the persistence of the U.S. blockade, and the pressure of selective migration, the brain drain. On the opportunity side, many competent scientists and engineers are committed to the socialist project. We have a primarily state-business system, which partakes in social development and medium- and long-term projects. We have an educated people and a climate of social cohesion that is admired elsewhere. And we have national sovereignty, which we know how to defend.

On this foundation, we must:

- Resume our development of the science, technology, and innovation system, making it grow ahead of the economy by treating it as a motor of development, not its distant consequence.
- Design quantifiable and bold national objectives for scientific-technical development, integrating the economic development programs we widely debate.
- Increase business financing of scientific activity, including university science, while maintaining a balance between business financing and budgeted financing, which is the financial expression of the balance between short-term and long-term objectives, without which no strategy would be sound.

- Perfect the legal framework for university-company relations and not fall into the trap of copying the U.S. system of commercial transactions on intellectual property, which is increasingly criticized as dysfunctional, even in industrialized countries.
- Outline proactive strategies for international collaboration since universities are the gateway for knowledge and technology and critical connections to global scientific-technical development.

The fruitfulness of the interaction between universities and the economy does not depend solely on what we do at the former. It also depends on the companies' behavior. This means that all the actions we implement to create incentives for companies to innovate (one of them is the exposure of companies to the export market) will result in a more intense and effective connection with universities. High-technology companies must be the vanguard in these interactions, but ultimate success depends on many companies, from one sector or another, also doing so and noticing positive consequences of their economic performance. The regulatory framework we build for companies will also have a decisive influence on the connectivity between the business world and the university world, a connection that will be more fruitful the more we keep the specificities of each of them. The model we need must emerge from our positive and negative experiences and from the debates. Creativity about this can make the difference between our development and stagnation.

10. How do the dual currency and exchange rate impact high-technology companies?

In implementing the guidelines approved by the Sixth Congress of the Cuban Communist Party (PCC), eliminating dual monetary and exchange rates was a priority. By the time this book is published, that process may be underway, and several of the following ideas may have become outdated.[16] However, the question is pertinent given that the book's content is based on experiences from 1995 to 2013 when the dual currency and exchange rate system was in force. This duality certainly influenced our nascent high-tech

companies, not because they are high-tech but export-oriented. As I have noted, a reciprocal link exists in a small country between high technology and exports. The large fixed costs of quality systems and the internalization of research in companies cannot be subsumed in the income of a company in a small country when it is limited to supplying a small domestic demand.

The equivalence between the peso and the dollar in the Cuban business economy is equivalent, in practice, to an overvaluation of the Cuban peso. And, in any country, the overvaluation of the national currency puts exporting companies at a disadvantage. However, this was not tragic for the biotechnology sector since we operated with a double financial balance in foreign and national currency, each with its own internal logic. And the direct attention to biotechnology centers from the country's highest management level protected them from the effects of accounting distortions that could have derived from the dual currency and the peso's overvaluation. Yet the system must be rearranged to operate with a single currency and avoid these distortions. That process is underway, and it will not be easy.

Economic theory utilizes the notion of "Dutch disease" to refer to the overvaluation of the exchange rate generated by the influx of foreign currency into countries that export raw materials.[17] The consequence is the loss of export competitiveness in all companies not linked to the main exportable product, given that they operate with an overvalued domestic currency. This is exemplified by the effect the export of gas discovered in the North Sea had on the Dutch economy in the 1960s. Hence the name "Dutch disease."

We have had our variant of this phenomenon in the overvaluation of our national currency sustained for a long time through our favorable exchange relations with the socialist camp. The high valorization of our sugar in the foreign trade with the USSR constituted vital support for the stability of our national currency, which translated into an increase in its value. This was beneficial while it lasted since it also meant an increase in the purchasing power of wages and, ultimately, in the workers' standard of living.

We lost this preferential trade (which we call "fair trade") in 1991. The dual currency and exchange rate was one of the measures we developed to cope with the Special Period, and it worked. But like all good medicine, it should be only used when needed and not for too long because side effects will appear. Eliminating the dual currency and exchange rate will benefit export sectors such as biotechnology, and we must prepare ourselves to make the most of this opportunity. But this is not a silver bullet for all problems. When we eliminate the monetary and exchange rate duality, the "Dutch disease" risk will persist if the equilibrium of the external balance is based on two or three products or services at a privileged price, making everything else less competitive. Two or three leading lines of export, whose income finances the rest of the economy, could give us a good positive balance in the external balance, but they will not stimulate industrial development alone. Our economy is an open one, and increasingly so. The viability of many of our products will increasingly depend on their competitiveness in the global economy. The only effective antidote is diversifying foreign trade vis-à-vis products, services, and recipient countries. This is our everyday battle.

11.* Why *didn't a knowledge economy emerge in the countries that had advanced the most toward socialism, such as the USSR and the German Democratic Republic (GDR)?

Given the magnitude of the dissolution of the USSR, Cubans' different explanations of this cataclysm influence our attitudes toward the economic and political decisions we make in Cuba. Although socialism was not dismantled in Cuba because we knew how to avoid it, it is our task to analyze what happened in other countries.

I will not attempt that analysis here. It is not the right context, and I do not have enough experience or information to attempt it. I will limit myself to examining one component of such an analysis, which is relevant to this book and is frequently absent in articles and books on the subject. This component is the connection between science and the economy and the growing importance

of that connection. The problems that led to the demise of the USSR have deep roots in its economic performance. The ideologues of capitalism try to present this fact as evidence that the idea of socialism (social ownership of the means of production and a planned economy) has birth defects and thus cannot work. But such a conclusion, in addition to having a clear reactionary ideological intent, does not withstand the force of the data.

The evidence shows that industrial production grew at an average annual rate of 11 percent during the first two five-year plans in the USSR. By the late 1930s, the USSR had overcome the technological gap with Germany and was immune to the vast global economic depression of the 1930s. After emerging victorious from the Great Patriotic War, the USSR economically recovered from its devastating effects, and its GDP grew by more than 5 percent per year from 1951 to 1970, a rate higher than that of the United States. The USSR came to produce 20 percent of the world's industrial production, which was only 4 percent before the October Revolution. At the same time, wages grew, and the working day was reduced to forty hours (thirty-five hours for strenuous jobs). These achievements occurred under the system of state ownership and central planning.

But starting in 1975, GDP growth fell below 3 percent. The real per capita income of the Soviet people, which in the 1960s grew at 6.8 percent per year, began to slow down, reaching 2.1 percent in the five years from 1981 to 1985. Between 1979 and 1982, the production of industrial goods contracted by 40 percent.[18] What happened? Why did the economic system work well in the thirty years before 1975, and its performance declined afterward? These are the data (with slight variations depending on the sources), and they are clear. Controversies arise when it comes to interpreting them.

Some interpretations focus on the malfunctioning of the production management system, bureaucratic expansion, the burden of military production, the increase in the cost of access to natural resources, political errors, narrow-minded economic propensities

by directors, the influence of the West's consumer society, and other factors, all of which very likely played some causative role. Social scientists will continue this analysis. I will add a factor that, unfortunately, remains understudied in the literature. Namely, in the second half of the twentieth century, global production changed under the influence of rapid technological development and the globalization of the economy. The period from 1950 to 1970 was still a stage of extensive growth, with large industrial production, large consumption of natural resources and energy, with standardized products and production systems intended, within large countries, mainly to satisfy their domestic demand and where the links with scientific development within universities and science academies were still distant.

Technological development and globalization, facilitated by reduced transportation costs and increased production scales, began to transform the landscape into an intensive growth model, with rapidly changing products and technologies, less content in natural resources and energy, and greater intangible content of knowledge. In addition, productive chains existed that traversed national borders to generate increasingly sophisticated products and services, of which a growing part was destined for exports. World trade in industrial goods has increased fivefold in the last thirty years.[19] In the industrialized world, investment is redirected toward high-tech areas, which are more profitable than others.

The knowledge economy has the accelerated application of scientific results to production among its distinctive features. Two examples suffice. The laser was first seen in a laboratory in 1960, and in the 1980s, it was a component of widely consumed items, such as compact discs. The enzymes that allow genes to be cloned and expressed were discovered in the 1970s, and recombinant insulin, the first product of modern biotechnology, became available in 1982. Therefore, the slowdown in the economic development of the USSR cannot be explained by arguing that the system worked well at one stage and began to make mistakes later. A more feasible explanation is that the management system of the

economy worked well (and better than capitalism) for one type of productive forces, but the level of development of the productive forces changed. This is an oversimplification of reality (all scientific explanations, including the laws of physics, are reductionist). It is not the whole explanation, and it may not be the main component of the explanation, but it must be part of the analysis, and it is surprising how often it is left out of the equations.

Science is thus an important factor. In the 1980s, the USSR had one-quarter of the world's scientists and half of the engineers. Its successes in space exploration symbolize its scientific development. Therefore, the question is not science but the connections of science with production and the mechanisms whereby these connections occur, which are expressed in technical development.

Ernesto Guevara shrewdly diagnosed the problem in 1965, writing that "technology has remained relatively stagnant in the vast majority of the Soviet economic sectors. . . ."[20] Fidel Castro returned to the subject when he visited the USSR in 1986 and, in his speech before the Twenty-Seventh Congress of the CPSU, he spoke of the "challenge brought by the development of the economy at a sustained and high rate, under the consistent and immediate application of the advances of science and technology."[21]

These are the causes, or at least some of them. Now the analysis must move to the causes of the causes, which is much more difficult and uncertain. Why were there insufficient connections between a large and excellent scientific base and a large and effective industrial base? Part of the answer is probably in the organization of the economy that can facilitate or hinder the rapid application of the results of science and technology. Detailed and rigid planning and directing the economy with administrative methods and highly centralized decisions certainly do not create a fertile context for innovation in companies. Social ownership of the means of production, an inalienable principle since it is the basis of social justice, was confused with the centralized administration of business decisions in the socialist experiences of the twentieth century. They are not the same thing.

This has old historical roots, which must be understood before elaborating any critique. In the nineteenth century, scientific socialism was the cultural heir of the rationalism and Enlightenment of the eighteenth century and was based on the success of the natural sciences of the time, mainly physics and mechanics. From there arose the reductionist program that has dominated the natural sciences for the last four hundred years, and that was brilliantly summarized in this quote by Albert Einstein: "The grand aim of all science is to cover the greatest number of empirical facts by logical deduction from the smallest number of hypotheses or axioms."[22] Many thinkers applied this approach to economics.

This reductionist rationalism coincided historically with the origin of modern socialism and influenced it. This led to the idea that the consistent application of certain laws of the economy could serve us to predict and direct economic development. The original ideas of mechanical rationalism are four hundred-years-old, but their echoes have reached the ledgers we must fill out today for next year's planning in our companies. This is not a matter of now making room for irrationality but of recognizing that things are more complicated than we thought, as has also been necessary in the natural sciences.

From biology, we know that living systems evolve by adaptive selection, that is, by the accumulation of changes generated almost at random (exploring the realm of what is possible), followed by a selection and fixation of those changes that produce evolutionary advantage. If companies resemble this and the economy must once again be nourished by the natural sciences, we will have to open spaces for innovation and exploration in companies. At first, this will have unpredictable consequences—species may become extinct—but the connection of innovation with production values selects those advantageous changes. Will we be able to capture this process in the economic model that we are building? Socialism allows for it and can integrate it better than the market economy. The young generations of Cuban socialist businessmen have the task of making this a reality.

12. How does the U.S. blockade of Cuba affect the development of its high-technology companies?

This would seem an unnecessary question. The blockade affects all spheres of national life. It will go down in history as one of the most immoral actions that one nation has undertaken against another, this time in a sustained manner for more than a half-century, harassing millions of people who were not even born when the events used as pretexts occurred.

That the Cuban people have known how to resist and emerge victorious from this challenge will also go down in history. We could leave the analysis here with the ethical and political judgments. But it is necessary to continue analyzing this phenomenon to continue defeating it. For this, it is not enough to say that the blockade negatively affects our development but also to dissect the mechanisms whereby it does so. And, in this sense, the question is not trivial. The blockade is a perverse phenomenon, but from the standpoint of imperialist interests, it is not a stupid choice. And it is not simply punishment or revenge, although it has much of that. It is a strategy.

Why do they keep it, then? Nobody believes that it is to recover certain properties, that is, nationalized companies that no longer exist, or if they still exist, are very old. Nor is it to seize our few natural, oil, and mineral resources, water reserves, or large tracts of land. The eleven million Cubans are not a market on which the profitability of U.S. companies depends. The real reason is not to be found in the past but in the future. It does not lie in our social system's weaknesses but in its virtues. The U.S. blockade seeks to prevent the unfolding of the enormous possibilities of developing the economy, culture, and social life under socialism. Deep down, they compliment us by keeping the blockade, although they will never admit it. They know, or at least intuit, the potential of socialism. A country that makes its material wealth grow based on the education and spiritual wealth of its people and on the equity that derives from social ownership of the means of production and distributive justice would be too clear evidence that the solutions

to the problems facing humanity today are not on the path of capitalism nor in the subordination to the interests of the developed capitalist countries. Thus, they need to show that our system "does not work," hence the blockade.

And this is also why the blockade will continue, although it changes shape because it does not derive from conjunctural situations related to the Cold War but from the United States' essential need to defend its socioeconomic system and to discredit any alternative. We cannot expect the shark to become a vegetarian. Therefore, we must prepare ourselves and the future generations of Cubans to continue facing this blockade. For this, it is important to examine the multiple ways in which it affects us.

The first is obvious: the resources available to our economy, the costs of what we must import (more expensive and from farther away), and the complexity of our financial transactions, considering the dominance of the U.S. dollar in international finance. Many of the inputs needed by the high-tech industry are produced in the United States or have U.S. components. The second is market access. This general problem affects all sectors, especially the development of high-tech companies. These companies need to complete their economic cycles in large markets. High technology entails high fixed costs since companies subsume large research costs and sophisticated quality systems. These companies cannot be profitable by serving domestic demand or the demand of other small countries.

For instance, in biotechnology, it is estimated that, at present, 70 percent of all that is sold in the world (in monetary terms) takes place within the United States. Then come the markets of Europe and Japan, and the rest of the world gets the remaining marginal fraction. There is a lot of recent literature on "emerging countries" (Brazil, China, India, Russia, South Africa, and Indonesia, among others) and the growing space they occupy in the world economy.[23] But their portion of trade in high-tech products is still small. The transactions on high-technology products in the most developed countries must occur through negotiations with large companies

from those countries that control the markets. And for companies outside the United States, the blockade, although it does not have extraterritorial legal validity, nonetheless has a subtle but effective deterrent effect since many companies have large interests in the United States or operate through its banks and fear retaliation. All this adds to the unfair perception of Cuba as risky. There are examples every day. When this chapter was written, we had complex negotiations with a large company that told us it could not "risk a sanction like the one the United States imposed on the Bank of Paris because we would go bankrupt."[24]

The third way the blockade affects the development of high-technology companies, beyond the access to supplies and markets, is by obstructing access to knowledge itself. The phenomenon we have discussed throughout the book, namely, the growing connection between science and production, although having older historical roots, is essentially a phenomenon of the second half of the twentieth century. Science demonstrated its productive potential during the Second World War in military industry. Radar, rocketry, nuclear weapons, antibiotics, and blood plasma were decisive for the war's outcome. The United States emerged from it with its industry intact, the largest gold reserves, the dominant position in world finance, and hundreds of immigrant scientists from Europe. A large part of that scientific potential was redirected to civilian industry, then without competition from Europe, the USSR, or Japan, which had all been devastated by war.

Thus, it is no wonder that the United States has assumed the hegemony of global scientific research. It accounts for 35 percent of world spending on research and development (China follows with 12 percent), 20 percent of scientists, 27.7 percent of scientific publications, and 41.8 percent of patents.[25] Likewise, the technical regulations that later became world standards were created in the United States. The blockade also tries to decouple us from the world flows of knowledge and technologies, in which the United States is the chief node. This effect is as important as financial resources, supplies, and markets. The disconnection of Cuban

science from the world networks of scientific exchange is the aim of our enemy. The deployment of the widest possible network of scientific exchange should be ours. As Martí said, "Plan against plan."

13. What is the role of Latin American integration and other integration spaces in expanding the knowledge-based economy?

Latin American integration entails many diverse opportunities in all sectors of the economy, which have been the subject of various studies. Here we will focus only on one—albeit very important—element: the knowledge economy.

Latin American economies have grown in the last decade, led by left-wing governments that, with their own particularities, left behind neoliberal privatization and deregulation and resumed an independent path based on the recovery of control over natural resources, the reinforcement of state intervention in the economy, Latin American integration, and social inclusion. These are progressive processes, and we Cubans are proud to have contributed to the germination of these seeds and to have participated in the process.

However, industrialization and technical progress are imminent tasks. Latin America's foreign trade continues to be based on primary products, and the tendency continues to increase. For example, this "primarization" of the Latin American economy is expressed in the reduction of the GDP fraction corresponding to industrial production, which fell from 12.7 percent from 1970 to 1974, and to 6.4 percent from 2002 to 2006.[26] Advocated by the United Nations Economic Commission for Latin America and the Caribbean (ECLAC) in the 1960s, import substitution industrialization to satisfy domestic demand is no longer viable in the twenty-first century.[27] The alternative is the development of high-value-added products. This is so for all of Latin America and much more for Cuba, which does not have mineral resources or large agricultural productions to serve as the engines of the economy.

What can Latin American integration contribute to industrialization based on high-technology products? Essentially three

things: market volume, production chains, and a shared vision of the functions of the state in the economy and social development. The first, namely, the expansion of economic space, is essential in general but especially for high-tech industries. The globalization of the economy, involving lower transportation costs and technological development, and facilitating larger production scales and lower fixed costs, render many industries unfeasible if they are to serve a small domestic demand. This was not the case, at least to such an extent, in the 1960s, when Latin American economists embraced the idea of national industrialization through import substitution.

At present, if small countries develop industries with their domestic markets in mind, the realization that it is cheaper to import than to produce will always come at some point. This dependency on the scale of production to attain viable costs is greater the higher the technological level of products since they contain a larger component of fixed costs. The possibility of producing for the whole Latin American demand can grant viability to high-technology industries that otherwise would not find it within their domestic economic spheres. And they would not be able to seek it in the Northern markets either since they are protected by enormous regulatory barriers.

Latin American integration should also allow us to build an integrated regulatory environment. To varying degrees, all countries have technical regulations for products, which must guarantee acceptable quality standards. This is most evident in medicines and then in food, but it is a trend that is progressively spreading to all sectors of production. Today's industrialized countries push for regulations to be consistent with the standards they have reached after a long development process. This practice serves as an entry barrier and prevents more producers from emerging. Quality standards that protect consumers are essential, but there is a fine line between guaranteeing quality and guaranteeing the monopoly of rich countries, and establishing where this line lies is not easy. Latin American integration can contribute to building a common

position on this issue, which would be another important step to making space for developing high-technology companies in the region. The existing dialogues between the pharmaceutical regulatory agencies of Cuba, Brazil, and Argentina are a starting point.

The second function of integration has to do with productive chains. One of the limitations of the attempts at substitution industrialization promoted by ECLAC from 1950 to 1960 was that they did not achieve sufficient national integration of the production process components, which translated into greater dependence on imported inputs.[28] This has also been the case in Cuba, where the vanguard of our access to high technology, namely, the biotechnology industry, has suffered from a weak integration to national production, limiting its multiplying effect on the rest of the industry. This is a very difficult problem to solve since the integration of a cutting-edge industry with other national industries depends on the level of technological development in the latter, and it is often necessary to decide whether to speed up the development of a sector, even if import dependencies are created, or to build national production chains, even if the cutting-edge sector's ability to access markets slows down. But in the end, for development to be sustainable, we will always need value chains across different industries. As an African proverb says: "If you want to go fast, go alone; if you want to go far, go together."

One possible function of Latin American integration would be the construction of productive chains within the region. Seen as a whole, it is more likely that we will find the components of these production chains in the entire continent. This will require political will, which also depends on regional regulatory synchronization decisions.

Finally, an essential function of regional integration is constructing a shared vision of the ultimate goals of economic development, of the balance between material and cultural and spiritual development, and of that between individual and collective decisions. The economy is not a set of mathematical formulas aimed at increasing GDP. Development strategies are rooted in a shared ethic, values,

and a common conception of quality of life. The economy is just a means to attain this. To the same extent that the Latin American countries can share those values and objectives, common economic development strategies will become feasible.

The transition to a knowledge economy must be one of the key strategies of Latin American integration. At the same time, integration makes this possible by creating large room for demand, the option of establishing productive chains, and the internal regulatory coordination that this economy needs. Cuba has the possibility of making a very important contribution to achieving Latin American integration on these bases.

The Cuban Revolution was radical in many ways, especially regarding social equity, national sovereignty, the role of the state in directing the economy, and the massive investment in human capital. It was more radical than is possible today for other socialist experiences in the region. And this Cuban radicalism was very creative. This historical performance now puts us in a position to contribute to the integration of Latin America, especially concerning the construction of a knowledge-based economy. Cuban doctors, the supply of pharmaceutical and biotechnological products to several countries in the region, educational programs, and other ongoing endeavors represent a starting point. The most complex and promising is yet to come, but it will not come alone. We must build it with effort and the constant wisdom needed to discover what is really feasible.

14. **What** ***are the risks of the fluctuation and exodus of highly qualified and talented specialists? How can we counter it?***

I deal with this subject in the first chapter of this book. However, it is appropriate to return to it, since it is based on an article written fifteen years ago. The issue is still very important, but some contextual elements have changed, especially in Cuba.

Before beginning the analysis, allow me to admit, in all frankness, that on a personal level, I have no sympathy for the highly qualified professionals who left Cuba amid our battle for development, much less for those who did so by deserting during a

mission abroad. Without ignoring the existence of cases in which personal life makes the decision to emigrate understandable, in most cases that I know of, what underlies the ostensible reasons is the attraction of superior individual material life, with wealth accumulated in the countries they go to. This attraction prevails over the perception of duty to others. And there is also the inability to feel the inner satisfaction that comes from knowing that one is a participant in a far-reaching, collective social endeavor.

Some have naïvely believed that their decision to emigrate is an act of individual free will in the face of their country's policies, without realizing that they have been manipulated by the immigration policies of other countries. But beyond personal perceptions, it is necessary to objectively analyze what is happening, the concrete forms and trends that this phenomenon takes in the twenty-first century, and its possible impact on the Cuban goal to build a knowledge economy. To put the issue in context, it must be emphasized that the scale of displacement and mobility of people has increased in recent decades and that the phenomenon is irreversible since it is linked to globalization. It has been estimated that by the end of the twentieth century, more than 2.6 billion people traveled by plane every year. Between 1998 and 2001, 3.6 million people arrived in the United States, Canada, and Australia, and another 4.5 million reached the fifteen states of the European Union.[29]

These figures do not reflect free movement since the receiving countries apply selective immigration policies that favor migrants who attained high technical qualifications in their countries of origin. In 2008, it was estimated that of the fifty-nine million immigrants living in OECD countries, twenty million were highly qualified.[30] Regarding Latin America alone, 1.2 million highly qualified people emigrated to the United States, Canada, and Britain in the last four decades of the twentieth century.[31] In sub-Saharan Africa, the African Academy of Sciences estimates that one-third of their trained scientists and technicians live and work in developed countries.[32]

If we consider the cost of training these scientists and technologists (which is mostly assumed or subsidized by the budget of the issuing states), these figures represent an enormous subsidy that underdeveloped countries give for free to the rich ones. The receiving countries do not assume any share of responsibility for the socioeconomic development of the poor nations that provide them with this subsidy. This is the global context, and we must continue to condemn it, even if we still do not understand all the practical consequences of this denunciation.

Let us now examine the situation in Cuba. First, we must state facts that are so obvious that we often do not mention them. The first is that Cuba has successfully faced the brain drain challenge. Although debates tend to focus on the numbers of those who emigrated, mainly to the United States, during the first decades of the Revolution, the tens of thousands of young people sent to study abroad returned in most cases (I am one of them). This would not have been possible without the commitment of most of these young people to the social project of the Revolution and their willingness to participate in it.

We are entering the twenty-first century in a more complex and riskier situation, where three new factors have appeared. First, our country has a great density of highly qualified human resources (some figures are offered in the previous chapters), generating a kind of gradient that favors emigration. Second, the Special Period's economic crisis deteriorated the living and working conditions of all Cubans, including scientists and technicians, and substantially reduced Cuba's ability to invest in science and technology. Third, in a historically necessary moment and through a politically bold decision, we modified our migratory regulations by making them much more flexible and eliminating restrictions that, at the time, were legitimate acts of defense but that ceased to have this role. The conjunction of these three factors has increased the emigration of qualified personnel and the risks that it entails, especially pertaining to the issue that concerns us here: the construction of a knowledge-based economy.

All this analysis helps us to understand the situation, but we must not seek solace in the fact that the problem is global or that it has causal factors external to Cuba. The analysis of this challenge should be the foundation of the strategies to face it. A doctor makes a diagnosis not for the intellectual pleasure of the analysis but to decide on a treatment. This is a very serious risk. How can we face it? The ideas expressed in this book, especially in this chapter, where it is not the author, but the readers, who have defined the topics, cannot be seen as a cookbook. No one has recipes for such a complex problem. But we must have the courage to make proposals. Here are some:

- Mostly, the brain drain problem does not require any specific policy to be addressed. In fact, some policies may do more harm than good. What matters is to tackle its root causes rather than the distal consequences. The effective policy is to resume the growth of the national science and technological innovation system and the investment in scientific-technical development as soon as the material conditions allow us to recover from the damage caused by the Special Period. In addition, we must expand our economy's high-technology sectors. Although the problem will continue (since it has global causes), the brain drain risk will decrease because of an expanding system of science and technological innovation.
- An important reason for the emigration of highly qualified personnel is the search for working conditions better suited for deploying their creative potential. But modern scientific development is a collective human enterprise and not the work of isolated individuals, as it was perhaps one-hundred years ago. And scientists know that beyond an acceptable threshold of working conditions, scientific productivity is higher when they work within their own culture's framework, where all the possibilities of their communication and mobilization of collective action occur.
- The working conditions of highly qualified personnel do not

only entail the quality of the equipment. They involve the intensity of exchanging ideas with their peers in other countries. The scientific-technical development of the twentieth century had a growing specialization of labor among its consequences. This implies that productive exchanges of ideas and collaboration in a specific specialty do not frequently occur within national borders, especially in small countries. For example, a scientist working on computer models of protein structure must have systematic exchanges with other specialists in the area, and there are not many in a small population. Creating conditions and spaces for these exchanges to occur systematically does not imply a brain drain risk, as some short-sighted people fear. On the contrary, the intensity of these exchanges is the guarantee of productivity and the retention of talent within our context.

- Our high-technology companies and scientific and higher education centers must further expand their international collaboration networks and especially take them to the level of collaboration among institutions or groups rather than individuals. The scientific and technical collaboration systems established by today's developed countries often have the perverse characteristic of being drain instruments. But even when there is a genuine commitment to help the Global South countries develop, these systems have the intellectual limitation of conceiving scientific development as the development of individuals and not as the construction of institutional capacities. This stems from the individualistic culture of nineteenth-century capitalism, which, we must not forget, arose from merchants. Today's world is not like that, and we must help those who collaborate with us to overcome that limitation.
- Even if acknowledging that the main factor influencing the emigration of highly qualified personnel is working conditions rather than material living conditions, it is also true that the limitations vis-à-vis purchasing power and housing have had a growing weight in our specific context. This issue requires differentiated and urgent attention. In science and technological

development, the period between thirty and forty-five years is usually the most creative. At these ages, many people have not had the time or conditions to build a solid material foundation for their personal and family lives. We must support them in this, and the resources needed are not great.

- But even if we implemented the three previous ideas perfectly, this would not mean we would return to the *modus operandi* of the twentieth century's national science and technology systems. Today globalization affects science and technology even before other sectors. Twenty-first-century scientific institutions and high-tech companies will be more fluid organizations, nodes of collaboration networks that extend to other countries, and managers of transnational productive chains. They will also have rapidly evolving and short-lived projects and greater labor mobility. They will be gates through which knowledge enters and exits, and the defense of countries' national interests in their development paths will not consist in closing the doors but in making more knowledge and technology enter through them than leave.

The defense of our national interests will continue to be a morally indisputable objective. The cosmopolitan vision that culture gives us cannot lead to ignoring that we still (and perhaps for many years to come) live in a world of predatory interests and attitudes of the rich toward the poor. And this social prehistory can only be overcome by collective struggles and social consciousness. Everything we do for Cuba to enter the global flows of knowledge, technology, and economic processes must have the ultimate goal of contributing to mending the rifts in national and social inequality and putting our creative capacities at the service of humanity. We must continue defending our national project. The message here is that we must defend it differently. We won the battle against the brain drain in the twentieth century, and we won it well. We must win it in the twenty-first century with different tactics but the same humane purpose.

15. What are your views on direct foreign investment in our high-tech companies?

This chapter was written just a few months after the National Assembly of People's Power approved a Law on Foreign Investment and the Mariel Special Development Zone was inaugurated. Thus, at this time, it is not possible to offer a view on this subject supported by data. We will have to wait for concrete experiences of foreign investment in Cuba.

The ideas with which we can work today derive from studying foreign investment experiences in other countries, and it is very difficult to draw conclusions from them because they are very diverse. In Latin America, foreign investment has mostly generated foreign-owned companies with a minimal (3.2 percent) research-development component. Even when high-technology products are generated, what has been emerging in Latin American countries are fragments of the value chain, leaving research and development laboratories and the generation of new products and intellectual property in the core nations. In Asia, the national participation in company ownership derived from foreign investment has been larger, as has been the high-technology component in investments. But even in those countries, research and development by foreign investment companies has been focused on improving the efficiency of the production process and not on the generation of new products.[33]

In general, multinational companies conduct little research and development outside their countries of origin and spread little knowledge to the peripheral countries where they invest. Rather, they generally transfer standardized manufacturing procedures. The countries that have been recipients of foreign investment have had very different levels of success in counterbalancing this trend and creating technological development capabilities. Singapore has had one of the most successful experiences through strong government management of foreign investment.[34] In Singapore, the participation of multinational companies in their spending on research and development exceeds 40 percent. At the opposite pole, in Mexico, this figure is less than 2 percent.

We must use foreign investment as much as possible to raise our

capital formation rate and improve our productive infrastructure. But the development of high-tech sectors must be a task for our state companies, either by themselves or by forming part of joint ventures with foreign investment featuring a high technological component. Foreign investment in these sectors can work as a complement since the development of human capital in Cuba has created the capacity to quickly absorb cutting-edge technologies.

We must quickly prepare our nascent high-tech socialist companies to perform this function. This implies more technical manager training and negotiation and business administration skills. The association with foreign companies is not only a source of financing for investment but also a source of knowledge and access to global commercialization and financial markets. In partnerships that have been successful in the biotechnology sector, these multiple functions have become clear when we have been prepared to make good use of them.

This brief comment on foreign investment would be incomplete if we didn't acknowledge that it is only part of a broader process: Cuba's entry into the world economy. Another element of the same process is the Cuban joint ventures abroad, which have had some successful experiences over the last decade, mainly in China. The globalization of the economy is an objective consequence of the development of the productive forces, and to succeed in this context we must think globally when designing our economic strategies.

THE ESSENTIAL AND THE PERIPHERAL: THE CUBAN CROSSROADS

To summarize the debate on the fifteen selected questions above, we must remember that we are discussing *the knowledge economy and socialism* and that we do so based on the intuitions generated by the emergence of a high-tech productive sector (biotechnology) in the last three decades of Cuban history. This debate does not (and cannot) include all the problems posed by the construction of socialism in Cuba amid the current global conjuncture. Yet placing

our necessarily limited topic in the context of broader problems is essential. The permanent analysis of these issues should allow us to ascertain, at every moment, what changes can best help us move forward while preventing them from being diluted among our thousands of daily tasks and urgencies. It should also allow us to identify those characteristics of our economic and social life that we should not change since they are linked to the values and the essence of the society we want to build.

The Cuban Revolution was a milestone in the history of Cubans, Latin America, and the so-called third world. Politics in many countries have been inspired by this example, which demonstrated that it is possible to attain sovereignty, social equality, and human development and resist the inevitable hostility of the rich in the face of any attempt of the poor to emancipate. The Cuban Revolution transcended the limits of what was possible. Any attempt to analyze the current Cuban reality cannot be separated from the historical conjuncture when the people seized political power in 1959. This was the time of the largest consolidation of the socialist experiment in the USSR (symbolized by the first human in space in 1961), the Cold War, the decolonization of Africa, the rise of the third world to a central position in world politics, and of dictatorships in Latin America.

The Cuban Revolution fulfilled its historical role then, with indelible impacts in Latin America and Africa. But we now have new tasks for the new generations of Cubans. These new generations should assume their tasks and understand that they should go beyond the narrow horizon of what is or is not available at the corner store or the status of prices. The core of our current tasks is the interrelation between human and economic development. The strategy of constructing human development from the redistribution of the wealth expropriated from the bourgeoisie in the 1960s and later from the management of economic relations with the European socialist bloc fulfilled their historical cycle and are no longer feasible. The only viable option today is to build a virtuous circle for constructing economic development from

human development and vice versa. The Cuban Revolution must again show that the limits of what is possible can be transcended. Preserving socialist values cannot only be a moral imperative at the expense of economic efficiency. We must find a way for these values to become a lever for economic efficiency.

Today, Latin America is experiencing popular movements and left-wing governments that identify, to varying degrees and specificities, with this idea of the twenty-first century. The main battle will take place in the realm of the economy, centered on the challenge of placing human development and equity at the forefront, all while achieving the accelerated development of material production without sacrificing culture and the environment. Moreover, this must be done in the context of a more interdependent world economy, which, following the demise of the postwar social-democratic illusion, has returned to the path of unlimited expansion of inequality.[35]

We Cubans have very special challenges and opportunities in this battle, and once again, we have a lot to say. These specificities, which derive from our historical trajectory, assign us tasks different from those that other revolutionary processes may undertake. In Cuba, we are undertaking this revolutionary stage by seeking the right balance between state and non-state management but from a consolidated predominance of the state sector. Other countries must go the other way around. We do not have a domestic bourgeoisie that hinders the process and claims political power. We do have a majority social consensus that is the legacy of the Revolution. Cuba also boasts great wealth in human capital because of a half-century of socialist construction.

We can do things others cannot, broadening our space of possibilities. But we are also facing the aftermath of a long stage of economic limitations from the abrupt loss of economic ties with the European socialist camp and the enduring hostility of the most powerful nation on Earth. We have restrictions that others do not, which reduces our space of possibilities. That is our context, and we must design and select strategies for it. In choosing paths amid

the many different problems and possible decisions that arise every day, there are three underlying social equations: the right balance between economic efficiency and social equality, the right balance between centralization and adaptive flexibility, and the right balance between graduality and urgency.

We Cubans situate ourselves, with our attitudes toward each problem, at one or the other pole of these dilemmas or in the elusive golden mean. The path we take at these crossroads will outline our future. Non-state management schemes, cooperatives, self-employment, the acceptance of remittances, and payment by results in state companies, among others, are necessary measures aimed at increasing labor productivity. But they also widen income inequality. The level of social equality in Cuba is still higher than that obtained by other social processes, even revolutionary ones. But finally, will we have to choose between efficiency and inequality or social justice with material deficiencies?[36] Will we have to choose between rigid planning that sacrifices creativity for short-term savings and the broad decentralization of management that allows for exploring growth alternatives even though it also opens the door to squandering and corruption? The good news is that these dichotomies can be transcended. They constitute false dilemmas since the balance between both extremes is mediated by culture in its broadest sense: ethical, legal, and technical. Subjecting ourselves to the tyranny of these dilemmas would only be possible from a skeptical vision of culture created by humanity.

Culture allows us to increase our motivation for work and productivity without relying solely on economic incentives that generate inequalities. Culture allows us to expand the space for decentralized management and enter the world economy, while ensuring that these attributes always are used for noble social ends.

What is our margin to overcome these false dichotomies, and how fast can we do it? "Rendering the exploiters innocuous, rapping them over the knuckles, clipping their wings is the least important part of the job. That must be done . . . the second part of the victory [is] to acquire the practical ability to do what is economically

necessary . . . thanks to our correct policy, the people allowed us a deferment of payment and credit . . . But this promissory note is undated. . . . Either we pass this test in competition with private capital, or we fail completely." This sounds like a text written for today's debates, but the quotes come from a speech by Lenin to the Eleventh Congress of the Russian Communist Party (Bolsheviks) in March 1922.[37] It teaches us that the economy has always been at the heart of the revolutionary struggle once political power is attained. It also teaches us that revolutionaries always had deadlines for succeeding. Ultimately, the ethical, judicial, and technical cultures also determine the speed at which we can move forward.

The optimal and possible balances between efficiency and equity, centralization and flexibility, and gradualness and urgency are also determined by the developmental level of the productive forces. In the areas of our economy where productive organizations directly connected with science and technology (and with the external demand for high-tech products and services) have been germinating, we have room to experiment with motivation and productivity approaches. This must occur without great inequalities, uncontrolled or corrupt business management autonomy, or irresponsibly hasty accelerated evolution. Our accomplishments and lessons from our errors will be transmitted through multiple channels to the rest of the Cuban business fabric, contributing to designing that "possible country" we want to build.

As Armando Hart stated in 1995, "The key and main challenge of our modernity lies in placing education, science, and culture at the very center of decisions about economic development programs."[38] This is exactly what moving to a knowledge economy under socialism is about. To what extent can we do it? The space of possibilities will depend on the culture and values built over decades by the historical experience of the Cuban people. We sufficiently possess them to continue advancing and spreading our messages worldwide.

Notes

1. Introduction

1. Eric Hobsbawm, *Historia del Siglo XX* (Buenos Aires: Grijalbo Mondadori, 1999).
2. Ibid.
3. Fidel Castro Ruz, speech at Cuba's Speleological Society, Academy of Sciences, January 15, 1960, http://www.cuba.cu/gobierno/discursos/1960/esp/f150160e.html.
4. "Cuba's biotech boom," *Nature* 457 (2009): 130.
5. Agustín Dávila Lage, "Propiedad y expropiación en la economía del conocimiento," *Revista Ciencia, Innovación y Desarrollo* 6, no. 4 (La Habana, 2001): 24–37.
6. Agustín Dávila Lage, "La ciencia y la cultura: las raíces culturales de la productividad," *Revista Cuba Socialista* 3ra. Época no. 20 (La Habana, 2001): 2–21.
7. Agustín Dávila Lage , "La Economía del Conocimiento y el socialismo: reflexiones a partir de la experiencia de la biotecnología cubana," *Revista Cuba Socialista* 3ra. Época no. 30 (La Habana, 2004): 2–28.
8. Agustín Dávila Lage, "La Economía del Conocimiento y el Socialismo (II): reflexiones a partir del Proyecto de desarrollo territorial en Yaguajay," *Revista Cuba Socialista* 3ra. Época, no. 33 (La Habana, 2004): 3–23.
9. Agustín Dávila Lage, "Concetando la Ciencia con la Economía: las palancas del socialismo," *Revista Cuba Socialista* 3ra. Época, no. 45 (La Habana, 2007): 2–26.
10. Agustín Dávila Lage, "Sociedad del Conocimiento y Soberanía

Nacional en el siglo xxi: el nexo necesario," *Revista Cuba Socialista* 3ra. Época, no. 50 (La Habana, 2009): 19–31.

11. Agustín Dávila Lage, "Las Funciones de la Ciencia en el Modelo Económico Cubano: intuiciones a partir del crecimiento de la industria biotecnológica," *Revista Temas* no. 69/octubre-diciembre 2012 (La Habana): 31–42.
12. "Party's and Revolution's Guidelines of economic and social policy," Havana, 2011, http://www.granma.cubaweb.cu/secciones/6to-congreso-pcc/Folleto%20Lineamientos%20VI%20Cong.pdf.

2. Property and Expropriation in the Knowledge Economy

1. A version of this work was published in *Revista Ciencia, Innovación y Desarrollo* 6, no. 4 (2001): 24–37.
2. Alvin Toffler, *Power Shift: Knowledge, Wealth, and Violence at the Edge of the 21st Century* (New York: Bantam Books, 1990).
3. Peter F. Drucker, *Post-Capitalist Society* (Oxford: Butterworth-Heinemann, 1993), 166.
4. World Bank, *World Development Report: Knowledge for Development* (Oxford University Press, New York, 1998).
5. Fidel Castro Ruz y H. Pérez, "Apuntes para una Agenda del Sur," *Ciencia, Innovación y Desarrollo* 5 (La Habana, 2000): 51–61.
6. Drucker, *Post-Capitalist Society*.
7. Karl Marx, *Capital: A Critique of Political Economy*. Vol. III (Middlesex, England: Harmondsworth: Penguin, 1993), 199.
8. Drucker, *Post-Capitalist Society*.
9. Fidel Castro Ruz y H. Pérez: "Apuntes para una Agenda del Sur, *Ciencia, Innovación y Desarrollo* 5 (La Habana, 2000): 51-61.
10. Ibid., *Ciencia, Innovación y Futuro* (La Habana: Instituto Cubano del Libro, 2001).
11. Pierre Papón y Remi Barré, "Los Sistemas de Ciencia y Tecnología: Panorama Mundial," *UNESCO: Informe Mundial sobre la Ciencia* (Paris: Ediciones UNESCO 1996): 8–22.
12. Ernest Mandel, *El Capitalismo Tardío*, Ed. ERA, México, 1979. [Ernest Mandel, *Late Capitalism* (London: Verso, 1999.)]
13. German Velázquez and Pascale Boulet, *Globalization and Access to Drugs: Implications of the WTO/TRIPS Agreement*, World Health Organization, Geneva, 1997.
14. John H. Barton et al., "Reforming the Patent System," *Science* 287 (2000): 1933–1934.
15. Michael A. Heller and Rebecca S. Eisenberg, "Can Patents Deter Innovation? The Anticommons in Biomedical Research," *Science* 280 (1998): 698–701.

16. Karl Marx, *Capital: A Critique of Political Economy*, vol 1 (London; New York, NY: Penguin Books in association with *New Left Review*, 1992), 875.
17. Ibid. (New York: Penguin Publishing Group, 1992), 776.
18. Ernesto Guevara: cited by O. Borrego, *Che: El Camino del Fuego* (La Habana: Imagen Contemporánea Editions, 2001).
19. Heinz F. Dietrich, Raimundo Franco, and Arno Peters, *El Nuevo Proyecto Histórico* (Mexico: Ed. Nuestro Tiempo S.A., 1998).
20. Francisco Soberón, *Finanzas, Banca y Dirección* (La Habana: Instituto Cubano del Libro, 2000).
21. The General Agreement on Tariffs and Trade (GATT) was a multilateral treaty between many countries to promote international trade by lowering or eliminating trade barriers such as tariffs or quotas. It was enacted in 1948 and replaced in 1995 with the establishment of the World Trade Organization (WTO).
22. Fidel Castro Ruz, Speech at the Academy of Sciences, January 15, 1960, http://www.cuba.cu/gobierno/discursos/1960/esp/f150160e.html
23. Ernesto López Mola et al., "Biotechnology in Cuba: 20 Years of Scientific, Social and Economic Progress," *Journal of Commercial Biotechnology* 13 (2006): 1–11.
24. *Maquila* or *maquiladora* refers to factories that are largely duty free and tariff-free. They take raw materials and assemble, manufacture, or process them and export the finished product. *Maquiladores* are found throughout Latin America.

3. Science and Culture: The Cultural Roots of Productivity

1. A version of this work was published in *Revista Cuba Socialista* 3ra, no. 20 (2001): 2–21.
2. M. Bunge, *La Ciencia: su método y su filosofía* (Buenos Aires: Ed. Sudamericana, 1995).
3. José Martí, *Obras Completas* (La Habana: Editorial de Ciencias Sociales, 1991), 191.
4. José Martí, *Obras Completas* (La Habana: Editorial de Ciencias Sociales, 1991), 893.
5. Ibid., 40.
6. José Martí, "Carta a María Mantilla," March 25, 1895, *Obras Completas.* Epistolario, t. 5 (La Habana: Editorial de Ciencias Sociales, 1975), 145–149.
7. José Marti, *Obras Completas* (La Habana: Editorial de Ciencias Sociales, 1991).
8. Toffler.
9. Michael E. Porter, *La Ventaja Competitiva de las Naciones* (Buenos Aires: Javier Vergara Editor S.A., 1991).

10. Agustín Lage Dávila, "Ciencia y Soberanía: Los retos y las oportunidades," *Compilador SELA*, 1994.
11. Thomas Kuhn, *The Structure of Scientific Revolutions* (University of Chicago Press, 1962).
12. Karl Marx, *El Capital* (La Habana: Instituto Cubano del Libro, 1973).
13. V. I. Lenin, *What Is To Be Done?* (Stuttgart: Editorial Ditz, 1902).

4. The Knowledge Economy and Socialism: Reflections from the Cuban Biotechnology Experience

1. A version of this work was published in *Revista Cuba Socialista* 3ra. Época, no. 30 (2004): 2–28.
2. Fidel Castro Ruz, *Ciencia, Innovación y Futuro* (La Habana: Instituto Cubano del Libro, 2001); Fidel Castro Ruz, *Ciencia, Tecnología y Sociedad: Hacia un desarrollo sostenible en la era de la globalización* (La Habana: Ed. Científico-Técnica, 2004). *Anuario Estadístico de Cuba*, Oficina Nacional de Estadísticas, 2007.
3. The number of defended doctorates up to 2011 is 12,281.
4. United Nations Human Development Index 2013 [Naciones Unidas Índice de Desarrollo Humano 2013], http://hdr.undp.org/en/media/HDR2013_ES_Complete%20REV.pdf.
5. Albert Sasson, *Biotecnologías aplicadas a la producción de fármacos y vacunas* (La Habana: Elfos Scientiae, 1998).
6. In 2012, the organizations of the Scientific Pole merged with pharmaceutical Industry companies, giving rise to the organization BIOCUBAFARMA, currently with thirty-eight companies and 22,000 workers.
7. Pedro I. Más-Bermejo et al., "Cuban Abdala Vaccine: Effectiveness in Preventing Severe Disease and Death from COVID-19 in Havana, Cuba; A Cohort Study," *The Lancet*, September 23, 2022, https://www.thelancet.com/journals/lanam/article/PIIS2667-193X(22)00183-1/fulltext#%20.
8. "Omicron and the NHS: we need to look beyond hospital care to solve the pressures," Letter to the Editor, *British Medical Journal (BMG)*, January 21, 2022, https://www.bmj.com/content/376/bmj.o185/rr.
9. Gary P. Pisano, *Science Business. The Promise, the Reality, and the Future of Biotech* (Boston: Harvard Business Publishing, 2006).

5. The Knowledge Economy and Socialism: Reflections from Yaguajay

1. Agustín Lage Dávila, "La Economía del Conocimiento y el Socialismo: Reflexiones a partir de la experiencia de la Biotecnología Cubana," *Revista Cuba Socialista* 3 ra., no. 30 (La Habana, Época, 2000): 2–28.
2. A version of this work was published in *Revista Cuba Socialista* 3ra, no, 33 (La Habana, Época, 2004): 3–23.

3. Constitution of the World Health Organization, https://www.who.int/governance/eb/who_constitution_en.pdf.
4. http://localhost/yaguajay.
5. Sinai Boffill Vega et al., *Proyecto Yaguajay: Un modelo de gestió*n para el desarrollo local, 2008. http://www.monografias.com/trabajos62/proyecto-yaguajay/proyecto-yaguajay.shtml.
6. Sinai Boffill Vega et al., "La nueva universidad y el gobierno en la construcción de un complejo de actores para el desarrollo local en Yaguajay," *Revista de Educación Superior* XXVIII, La Habana (setiembre-diciembre 2008): 137–147; J. Núñez: "Educación superior y desarrollo local: la agenda emergente y sus demandas conceptuales," *Conocimiento académico y sociedad. Ensayos sobre política universitaria y posgrado*, Editorial UH, La Habana (2008):192–210.
7. Agustín Lage Dávila, "La Economía del Conocimiento y el Socialismo: Reflexiones a partir de la experiencia de la Biotecnología Cubana," *Revista Cuba Socialista* 3ra., no. 30 (La Habana: Época, 2004): 2–28.
8. In the late 1970s, a new set of institutions was created under the heading of "Popular Power." They were bodies with legislative powers whose membership was open to the masses. Popular Power exists at three levels: national, provincial, and municipal. The National Assembly of People's Power is Cuba's unicameral parliament. Its edicts are binding on the provincial assemblies. There are direct elections only at the municipal level.
9. Agustín Lage Dávila, *Ciencia y Soberanía: Los retos y las oportunidades*, compilador SELA (1994).

6. Connecting Science and Economy: The Levers of Socialism

1. *Revista Cuba Socialista* 3ra., no. 45 (La Habana: Época, 2007): 2–26.
2. Agustín Lage Dávila, "La Economía del Conocimiento y el Socialismo. ¿Hay una oportunidad para el desarrollo?" *Cuba Socialista* 3 ra, no. 41 (La Habana: octubre-diciembre 2006); Lage, "Socialism and the Knowledge Economy: Cuban Biotechnology," *Monthly Review* (December 2006).
3. Karl Marx, *Capital: A Critique of Political Economy* (London: Penguin Books in association with New Left Review, 1992), 875.
4. Fidel Castro Ruz, "Reflexiones del Comandante en Jefe: El robo de cerebros," *Granma*, July 17, 2007.
5. Antonio Negri, *Empire and Beyond* (Cambridge, UK ; Malden, MA: Polity), 3, 74.
6. Cuba's estimated 2023 population was approximately 11,012,000. https://www.britannica.com/place/Cuba.
7. J. C. Alfonso Fraga, "El descenso de fecundidad en Cuba: de la primera a la segunda transición demográfica, *Revista Cubana Salud Pública* 32, no. 1 (La Habana, Jan-Mar, 2006).

8. Cubans aged 60 and over represented about 21.6 percent of the population at the end of 2022. https://en.granma.cu/cuba/2023-03-02/faced-with-the-accelerated-aging-of-its-population-cuba-strengthens-its-attention-to-it.
9. Gary P. Pisano, S*cience Business. The Promise, the Reality, and the Future of Biotech* (Harvard Business School Press, 2006).
10. Marcia Angell, *La verdad acerca de la Industria Farmacéutica. Cómo nos engaña y qué hacer al respecto*, Colección Biografías y Documentos, Grupo Editorial Norma, 2004.
11. Ibid.
12. Caroline S. Wagner et al., *Science and technology collaboration: Building capacity in developing countries?* (Santa Monica: RAND, 2001).
13. Fidel Castro Ruz, "Reflexiones del Comandante en Jefe: El robo de cerebros," *Granma*, July 17, 2007.
14. Angela Casaña Mata, "Emigración de profesionales. Robo de cerebros en el siglo XXI," *Anuario Digital CEMI* (Centro de Estudios de Migraciones Internacionales), 2006.
15. Emil Sader, "La historia es un proceso abierto," *América Libre* no. 10 (Buenos Aires, enero 1997): 104.
16. José Luis Rodríguez García, *La perestroika en la economía soviética. 1985–1991. Análisis preliminar*. Ministerio de Economía y Planificación, Investigaciones Económicas Series.
17. Ibid.
18. Y. Vicente Prado, *Marco Institucional. Influencia en el crecimiento productivo en Cuba*. Bachelor's thesis, School of Economics, University of Havana, Havana, 2006.
19. Ernesto Guevara, "Sobre el sistema presupuestario de financiamiento," *Revista Económica Nuestra Industria* no. 5 (La Habana: febrero 1964).
20. Karl Marx, "Preface to *A Contribution to the Critique of Political Economy (1859),*" https://www.marxists.org/archive/marx/works/1859/critique-pol-economy/preface.htm.

7. Knowledge, Society, and National Sovereignty in the Twenty-First Century

1. Agustín Dávila Lage, *Ciencia y Soberanía: Los retos y las oportunidades*, SELA, compiler, 1994.
2. Ibid.
3. Eric Hobsbawm, *The Age of Empire, 1875–1914* (New York: Vintage, 1989).
4. Eric Hobsbawm, *The Age of Capital, 1848–1875* (New York: Vintage Books, 1996).
5. O. Martínez, "El Libre Comercio: Zorro libre entre gallinas libres," *Revista Cuba Socialista*, no. 32, (La Habana: 2004): 29.

6. According to the World Bank, as of December 2022, 648 million people in the world (about eight percent of the global population) live in extreme poverty, meaning that they subsist on less than US$2.15 per day, the current international poverty line (IPL). According to the UNICEF, WHO, and the World Bank Group, in 2022, stunting and wasting, indicators of poor nutrition, affected 22.3 percent of children under five years of age worldwide and 6.8 percent were affected by wasting.
7. Joseph E. Stiglitz, *Globalization and Its Discontents* (New York: W.W. Norton & Company, 2003).
8. Ibid.
9. Armando Hart Dávalos, *Ética, Cultura y Política* (La Habana: Ed. ORBE Nuevo, 2001).
10. José Martí, "Discurso en Liceo Cubano," Tampa, noviembre 26, 1891. http://www.josemarti.cu/files/DI06.pdf.
11. *Panorama Económico y Social, Cuba 2007*, ONE-National Office of Statistics, Havana, 2007 (www.one.cu).
12. The quote is from a letter John Quincy Adams, then U.S. Secretary of State, sent to Hugh Nelson, the U.S. Minister to Spain, on April 23, 1823. https://google.cat/books?id=PH0MAAAAYAAJ&pg=PA7&focus=viewport&vq=annexation&dq=editions:UOM39015038699305&output=html.
13. G. Duménil y B. Cassen, *El imperio de la Guerra Permanente* (Buenos Aires: Capital Intelectual S.A., 2007).
14. E.A. Martínez, "Plan de la Economía Nacional de 1964," *Revista Cuba Socialista* (La Habana: March 1964): 1–22.
15. Ibid.
16. Alvin Toffler, *Powershift* (London: Bantam Press, 1990).
17. Stiglitz, 247.
18. Adam Smith, *The Wealth of Nations* (Madrid: Ed. Alianza, 2002).
19. After fourteen years, members of the World Trade Organization ended the Doha round of negotiations on a global trade system in 2016.
20. The Free Trade Area of the Americas (FTAA) was a proposed agreement to eliminate or lower trade barriers among all countries in the Americas except Cuba. Negotiations to establish the FTAA ended in failure to reach an agreement by the 2005 deadline.
21. The Bolivarian Alliance for the Peoples of Our America (ALBA) is a regional bloc organized in 2004 that promotes social, political, and economic integration in Latin America and the Caribbean. It was conceived by Venezuelan president Hugo Chávez and established by Venezuela and Cuba as an alternative to the U.S.-led Free Trade Area of the Americas.

22. José Martí, *Obras Completas* (La Habana: Editorial de Ciencias Sociales, 1991).
23. https://inside.sfuhs.org/dept/history/US_History_reader/Chapter14/MLKriverside.htm.

8. The Function of Science in the Cuban Economic Model

1. "Lineamientos de la Política Económica y Social del Partido y la Revolución," VI Congreso del Partido Comunista de Cuba, 2011.
2. A version of this work was published in *Revista Temas*, no. 69 (La Habana: October-December 2012): 31–42.
3. Agustín Dàvila Lage, "La economía del conocimiento y el socialismo: Reflexiones a partir de la experiencia de la Biotecnología Cubana," *Revista Cuba Socialista* 3ra. no. 30 (La Habana: Época, 2004):2–28.
4. Agustín Dàvila Lage, "La Economía del Conocimiento y el socialismo: ¿hay una oportunidad para el Desarrollo?" *Revista Cuba Socialista* 3ra. (La Habana: Época, 2006): 25–43.
5. "Lineamientos de la Política Económica y Social del Partido y la Revolución," VI Congreso del Partido Comunista de Cuba, 2011.
6. A medicine to treat patients who suffer from diabetic foot ulcer.
7. Agustín Lage Dávila, "Conectando la ciencia a la economía: Las palancas del socialismo," *Revista Cuba Socialista* 3ra. no. 45 (La Habana: Época, 2007): 2–26.
8. The UN International Organization for Migration estimated that in 2020 there were approximately 281 million international migrants in the world, which equates to 3.6 percent of the global population. See: International Organization for Migration. *World Migration Report 2022*. https://worldmigrationreport.iom.int/wmr-2022-interactive/.
9. As of 2019, private (business) investment in research and development was 74.5 percent in the United States; 79.2 percent in Japan; 68,9 percent in Germany; 65.8 percent in France. See: "Research and Development: U.S. Trends and International Comparisons," https://ncses.nsf.gov/pubs/nsb20225/cross-national-comparisons-of-r-d-performance.
10. Agustín Lage Dávila, "Sociedad del conocimiento y soberanía nacional en el siglo XXI: El nexo necesario," *Revista Cuba Socialista* 3ra., no. 50 (La Habana: Época 2000): 19–31.
11. Gang Zeng, Ingo Liefner, and Yeufang Si, "The Role of High-Tech Parks in China's Regional Economy: Empirical Evidence from the IC Industry in the Zhangiang High-Tech Park, Shanghai," *Erdkunde* 65, no. 1 (2011): 43–53.
12. Agustín Dàvila Lage, "Global Pharmaceutical Development and Access: Critical Issues of Ethics and Equity," *MEDICC Review*, July 2011: 16–22.

13. Kevin Watkins et al., "Informe sobre Desarrollo Humano 2005. La cooperación internacional ante una encrucijada: Ayuda al Desarrollo, comercio y seguridad en un mundo desigual", Publicado para el PNUD, Ediciones Mundi-Prensa, 2005. [*Human development report, 2005: international cooperation at a crossroads; aid, trade and security in an unequal world*].
14. "Lineamientos de la Política Económica y Social del Partido y la Revolución," VI Congreso del Partido Comunista de Cuba, 2011.
15. The Cuban population aged sixty and over was about 21.6 percent at the end of 2022, the only segment of population that is increasing. See: Elías Amor Bravo, "Cuba's Actions to Stop the Aging of the Population," *Havana Times*, February 23, 2023, https://havanatimes.org/opinion/cubas-actions-to-stop-the-aging-of-the-population/.
16. "UNESCO Science Report 2010. The Current Status of Science Around the World," *UNESCO Publishing*, 2010.
17. Ibid.
18. "Lineamientos de la Política Económica y Social del Partido y la Revolución," VI Congreso del Partido Comunista de Cuba, 2011.
19. Ibid.
20. Jorge Núñez, *Conocimiento académico y Sociedad. Ensayos sobre política universitaria de investigación y posgrado* (La Habana: Editorial UH, 2010); Fidel Castro Ruz, *Ciencia, Tecnología e Innovación: desafíos e incertidumbres para el Sur* (Ediciones Plaza, 2006).
21. José Luis Rodríguez, *El derrumbe del socialismo en Europa: del socialismo real al capitalismo salvaje* (La Habana: Editorial de Ciencias Sociales, 2011).
22. Agustín Lage Dávila, "La Economía del Conocimiento y el socialismo (II): Reflexiones a partir del proyecto de desarrollo territorial en Yaguajay," *Revista Cuba Socialista* 3ra, no. 33 (La Habana: Época, 2004): 3–23.
23. "Lineamientos de la Política Económica y Social del Partido y la Revolución, " VI Congreso del Partido Comunista de Cuba, 2011.
24. Cuban doctors play a primary role in the Mission Barrio Adentro Salud ("Into the Neighborhood Health Mission") social welfare program established in Venezuela under former Venezuelan president Hugo Chávez. See: Cubadebate, "Cuban collaboration: Principles and truths from Venezuela," May 28, 2019, http://en.cubadebate.cu/news/2019/03/28/cuban-collaboration-principles-and-truths-from-venezuela/.

9. The High-Technology Company and the Management of Discontinuities

1. Agustín Dàvila Lage, "La economía del conocimiento y el socialismo:

Reflexiones a partir de la experiencia de la Biotecnología Cubana," *Revista Cuba Socialista* 3ra. no 30 (La Habana: Epoca, 2004): 2–28.

2. NASDAQ, http://www.nasdaq.com/investing/glossary/n/nasdaq-stock-market
3. United Nations Development Program, *Human Development Report*, 2013, https://hdr.undp.org/content/human-development-report-2013.
4. Yordanka Criberio Díaz, "Contribución de la fuerza de trabajo calificada al crecimiento económico en Cuba. Principales determinaciones," Tesis en opción al grado científico de Doctor en Ciencias Económicas, Facultad de Economía, Departamento Macro-Microeconomía, Universidad de la Habana, La Habana, 2011.
5. Graphs by translator in *R*, using ggplot. Modified from those (in the original Spanish edition, 250–251. Lage used data from the *Human Development Report*, 2013. The translator used data from various sources, gathered by Our World in Data. Cf.: https://ourworldindata.org/grapher/average-years-of-schooling-vs-gdp-per-capita for the schooling graph, and https://ourworldindata.org/grapher/life-expectancy-vs-gdp-per-capita for life expectancy graph. The trends showed by Lage and the ones remade here by the translator are not identical, but they consistently go in the same direction. The figure for Cuba's average years of schooling in 2013 was inputted from the graph Lage shows. The translator inserted these figures in the text a little before Lage does in his original. This is because, in the translator's view, the placement here is more directly linked to the content in the preceding paragraph.
6. George Gilder, *Wealth and Poverty* (New York: Basic Books, 1981), 62, 118.
7. United Nations. *Inequality Matters: Report of the World Social Situation 2013*, 27. www.un.org/esa/socdev/documents/reports/Inequality Matters.pdf.
8. Instituto Finlay de Vacunas, https://www.finlay.edu.cu/en/.
9. Peter F. Drucker, "Knowledge-Worker Productivity: The Biggest Challenge," *California Management Review* 41, no. 2 (Winter 1999): 79–94.
10. Gary P. Pisano, *Science Business: The Promise, the Reality, and the Future of Biotech* (Boston: Harvard Business School Press, 2006).
11. "Algunas reflexiones sobre la transición socialista," Carta del Che Guevara a Fidel Castro, abril de 1965, https://www.lahaine.org/amauta/b2-img/CheFideltransicion.pdf.
12. The Ibero-American Network of Science and Technology Indicators (RICYT), 2012. Updated indicators are available at http:/bd.ricyt.org/.
13. Agustín Dàvila Lage, "Las funciones de la ciencia en el modelo económico cubano: intuiciones a partir del crecimiento de la industria biotecnológica," *Revista Temas* no. 69 (La Habana, 2012): 31–42.

14. Manuel Díaz-Canel, "Hacia un mayor impacto económico y social de la Educación Superior," *Revista Nueva Empresa* 8, no. 1 (La Habana, 2012): 3–10.
15. Simón Rodríguez, *El libertador del mediodía de América y sus compañeros de armas / defendidos por un Amigo de la Causa Social* (Arequipa, Peru: Publicación Arequipa, Imprenta Publica, 1830).

10. Management in the High-Technology Company

1. Agustín Dàvila Lage, "La economía del conocimiento y el socialismo: Reflexiones a partir de la experiencia de la Biotecnología Cubana," *Revista Cuba Socialista* 3ra., no 30 (La Habana: Época, 2004): 2.
2. Jim Collins, *Good to Great* (London: Random House Business Books, 2001; Jim Collins, *Built to Last* (New York: Harper Collins, 1997).
3. Stephen Barker and Rob Cole, *Brilliant Project Management: What the Best Project Managers Know, Say and Do,* 3rd ed. (Pearson Education Limited, 2014); David P. Norton and Robert S. Kaplan, *The Balanced Scorecard* (Boston: Harvard Business Review Press, 1996).
4. Barker and Cole.
5. José Rodríguez-Pérez, *CAPA for the FDA-Regulated Industry* (Milwaukee: Quality Press, 2011).
6. Agustín Dàvila Lage, "La Economía del Conocimiento y el Socialismo: ¿Hay una oportunidad para el Desarrollo?" *Revista Cuba Socialista* 3ra, no. 41 (La Habana, 2006).

11. The Knowledge Economy and Socialism: An Opportunity for Development

1. Alvin Toffler, *The Third Wave* (London: Pan Books Ltd., 1981).
2. Joseph E. Stiglitz, *Globalization and Its Discontents* (New York: W.W. Norton, 2003). [Lage cites the 2002 Taurus Edition in Spanish.]
3. United Nations Development Programme (UNDP). 2013. *Human Development Report 2013,* https://hdr.undp.org/system/files/documents/global-report-document/hdr2013encompletepdf.pdf?_gl=1%2A1sxhfx9%2A_ga%2ANjkwODI1ODE3LjE2NzY1OTA0OTQ.%2A_ga_TGHFVBQ9DR%2AMTY3NjU5MDQ5My4xLjAuMTY3NjU5MDQ5My42MC4wLjA.%2A_ga_3W7LPK0WP1%2AMTY3NjU5MDQ5My4xLjAuMTY3NjU5MDQ5My4wLjAuMA.
4. Pierre Papon and Remi Barré, "Science and Technology Systems: A Global Overview," in *World Science Report 1996*, ed. H. Moore (Paris: UNESCO, 1996), 8–22.
5. Ricardo Bielschowsky, "Evolución de las ideas de la CEPAL," *Revista de la CEPAL*, número extraordinario (1998): 21, https://repositorio.cepal.org/handle/11362/12121.

6. La Espina Rosa. *Carta de Rosa Luxemburgo a Frans Mehring, febrero de 1916,* http://espina-roja.blogspot.com/2010/02/164-aniversario-del-nacimiento-de-franz.html.

12. The Knowledge Economy and Socialism: Cuban Questions

1. Thomas Piketty, *Capital in the Twenty-first Century* (Cambridge: Harvard University Press, 2014).
2. The Council for Mutual Economic Assistance (COMECON) was an economic organization founded by the Soviet Union that, from 1949 to 1991, comprised the countries of the Eastern Bloc and a number of socialist states elsewhere.
3. José Luis Rodríguez, *La Perestroika en la economía soviética 1985–1991. Análisis preliminar* (La Habana: Centro de Estudios de la Economía Mundial, 2006).
4. Piketty.
5. "Lineamientos de la Política Económica y Social del Partido y la Revolución," VI Congreso del Partido Comunista de Cuba, 2011.
6. José Luis Rodríguez, *La Perestroika en la economía soviética 1985-1991. Análisis preliminar*.
7. NASDAQ: www.nasdaq.com/investing/glossary/n/nasdaq-stock-market.
8. Jim Collins and Morten T. Hansen, *Great by Choice* (London: Random House Business Books, 2001); Jim Collins, *Good to Great* (New York: Harper Collins Publishers Inc., 2001); Raquel Lorenzo Garcia, *Talento, Creatividad, Empresa* (La Habana: Academia, 2013).
9. Gary P. Pisano, *Science Business: The Promise, the Reality and the Future of Biotech* (Boston: Harvard Business School Press, 2006).
10. Lidia Britto et al., *UNESCO Science Report 2010. The Current Status of Science around the world*. UNESCO Publishing.
11. Martine Bulard et al., *El Atlas de Le Monde Diplomatique*. (Valencia: Ediciones Cybermonde SL).
12. Jorge Núñez Jover, *Conocimiento académico y Sociedad. Ensayos sobre política universitaria de investigación y posgrado* (La Habana: Editorial UH, 2010); Guillermo. L. Andrés-Alpízar, "El financiamiento de la ciencia. Crisis, asimetrías y privatización," *Revista Temas de la Economía Mundial* 23 (2013): 93–112; Jennifer Washburn, *University Inc.: The Corporate Corruption of American Higher Education* (New York: Basic Books, 2006); Vilma Hidalgo de los Santos and Yordanka Cribeiro Díaz, "Potenciar el impacto de la calificación en el crecimiento económico: necesidad impostergable en Cuba," *Revista Bimestre Cubana* CXII, no. 37 (2012): 71–97.
13. Andrés-Alpízar, 93–112.
14. Washburn, *University Inc*.

15. Criberio-Diaz and Hidalgo, 71–97.
16. Translator's note: Indeed, this was the case. On December 10, 2020, the Cuban government announced that monetary unification between the convertible peso (CUC) and the Cuban peso (CUP) would occur by the beginning of 2021. From then on, CUCs would only be accepted at exchange sites and banks. The final date for exchanging CUCs was December 30, 2021 (*cf.* https://www.bc.gob.cu/noticia/informacion-de-interes/1190) and https://blogs.lse.ac.uk/latamcaribbean/2021/02/10/day-zero-how-and-why-cuba-unified-its-dual-currency-system/.
17. W. Max Corden and J. Peter Neary, "Booming Sector and De-industrialization in a Small Open Economy," *The Economic Journal* 92, no. 368 (1992): 825–848.
18. Roger Keeran and Thomas Kenny, *Socialism Betrayed: Behind the Collapse of the Soviet Union* (Bloomington: iUniverse Inc., 2010). [Lage cites the Spanish version published by Havana's Social Sciences editorial.]
19. Bulard et al.
20. Ernesto Guevara, *Algunas reflexiones sobre la transición socialista. Carta a Fidel Castro,* April 1965, http://www.contextolatinoamericano.com/articulos/algunas/reflexiones/sobre-la-transición-socialista.
21. Fidel Castro, "Discurso ante el XXVII Congreso del Partido Comunista de la Unión Soviética," Palacio de los Congresos, Moscú, febrero 1986.
22. https://www.brainyquote.com/quotes/albert_einstein_112012.
23. University of Toronto BRICS Information Centre, http://www.brics.utoronto.ca/.
24. Johannes Werner, "French Bank Accepts Harsh U.S. Conditions, Pulls Out of Cuba," *Cubastandard*, July 1, 2014, https://www.cubastandard.com/french-bank-accepts-harsh-u-s-conditions-pulls-out-of-cuba-2/.
25. Brito et al.
26. José Luis Rodríguez, "Las alternativas actuales de la industrialización en América Latina," *Revista Espacio Crítico* no. 17 (2012), segundo semestre de 2012: 44–49, http://www.espaciocritico.com/sites/all/files/revista/recrt17/n17_a05.pdf.
27. Ricardo Bielschowsky, *Evolución de las ideas de la CEPAL* (1998), (https://repositorio.cepal.org/handle/11362/12121).
28. Bielschowsky.
29. Eric Hobsbawm, "War and Peace in the 20th Century," in *War and Peace in the 20th Century and Beyond* (Oslo, Norway: World Scientific, 2003), 25–40. [Lage cites the version in Spanish published by Crítica editorial in 2007 in Barcelona.]
30. Brito et al.
31. Bielschowsky.

32. Brito et al.
33. Alice Hoffenberg Amsden, F. Ted Tschang, Akira Gotō, "Do Foreign Companies Conduct R&D in Developing Countries? A New Approach to Analyzing the Level of R&D with an Analysis of Singapore," ADB Institute Working Paper 14 (Tokyo: ADB Institute, 2001).
34. Hwee Hua Lim, *Government in Business: Friend or Foe?* (Singapore: Straits Times Press, 2013).
35. Piketty.
36. Camila Piñeiro Harnecker, "Distintas visiones sobre el socialismo que guían los cambios actuales en Cuba," *Temas*, 70 (2012): 46–55.
37. Speech translated by David Skvirsky and George Hanna, https://www.marxists.org/archive/lenin/works/1922/mar/27.htm#fw01.
38. Armando Hart Dávalos, "Intervención en el evento internacional Pedagogía 1995," La Habana.

Index

absorptive capacity of technology, 113
Adams, John Quincy, 158
Advanced Research Projects Agency (U.S.), 213
Africa, emigration from, 285
agonistic capitalism, 37
Agreement on Trade-Related Intellectual Property (TRIPS; 1994), 33
AIDS drugs, 185
ALBA, *see* Bolivarian Alliance for the Peoples of Our America
Andropov, Yuri, 145
artistic culture, 56; *see also* culture
arts, *see* culture

bank credit, 252
bankruptcy laws, 266
Bayh, Birch, 139
Bayh-Dole Act (U.S., 1980), 139
BIOCUBAFARMA (firm), 257, 268
Biological Front (Cuba), 79
biology, 277
biotechnology, 14, 28–29; in capitalist countries, 137–38; Center for Molecular Immunology in, 120–22; in Cuba, 16–18, 78–82, 129–37, 172, 179–80, 188–89; export strategy for, 262; in high-tech socialist companies, 190, 197–200; impact of U.S. blockade of Cuba on, 279; intangibles in, 264–65; in international economy, 164–65; processes for, 82–85; productive forces and the relations of

production in, 209–10; under socialism, 93–95
Bolivarian Alliance for the Peoples of Our America (ALBA), 133, 183
brain drains, 37–40, 47, 125, 284–89; damage caused by, 143–44
Brazil, 183

capitalism: agonistic, 37; intangible assets in economies of, 262–63; knowledge economy and, 68–72; knowledge economy's clash with, 137–41; market failures in, 90–93; Marx on end of, 42; privatization of knowledge under, 25; state's role in economy under, 212
Carpentier, Alejo, 216
Castro, Fidel, 18, 72, 156, 192; biotechnology under, 79, 148, 172, 180; on brain drains, 125; Center for Molecular Immunology inaugurated by, 121; on national independence, 150; on science and technology in Soviet Union, 276; on science in Cuba, 16, 46, 74, 111, 128, 161, 197, 258; Scientific Pole of Biotechnology created by, 206; on social justice, 157; on socioeconomic development, 101; on vision statements, 220
Castro, Raúl, 270
Center for Genetic Engineering and Biotechnology (Cuba), 80, 206
Center for Molecular Immunology (CMI), 120–22, 206; intangible assets of, 263; management of, 219–21
centralization and decentralization, 115, 132, 146–47; in economy, 161
China, 183, 203, 291
colonization, 152–53
COMECON (Council for Mutual Economic Assistance), 251
commercial strategies, 224
Communist Party of Cuba, 170, 186; on economic and social policy, 17, 171, 189; Economic Policy Guidelines of, 253–54; on state socialist companies, 199
competitive advantages, theory of, 65–67
computing, 104, 192
COVID vaccines, 80
Cuba: biotechnology patents in, 51; biotechnology sector in, 78–82, 197–200; brain drain from, 143–44; direct foreign investments in, 289–91; education in, 74; high-technology sectors in economy of, 50; impact of U.S. blockade of, 278–81; knowledge economy in, 22, 76–78, 129–37, 242–45; national sovereignty of, 154–56; population of, 186–87;

scientific research institutions in, 74–75; scientific sector in, 114–17; scientists and GDP in, 70–71; scientists and technicians in, 47–48; support for scientific research in, 213–14; transition to knowledge economy in, 126–29
culture, 162–63; in continuum with science, 58–59; cultural determinants of scientific productivity, 60–63; equality and, 204–5; science and, as forms of knowledge, 55–56; in science-culture-economy triangle, 63–65; scientific development and, 54–55; scientific method and, 56–58; in theory of competitive advantages, 65–67
currencies and exchange rates, 271–73

decentralization and centralization, 115, 132, 146–47; in economy, 161
decolonization, 153
defense, 152
developmentalist theories, 174
direct foreign investment, 289–91
Dole, Robert, 139
Drucker, Peter, 22
"Dutch disease," 272, 273

economic development, 237; current context for, 175–76; developmentalist theories of, 174; in knowledge economy, 239–41; science and, 42–44, 75; scientific research and, 176–77; sustainable, 117
economics, theory of competitive advantages in, 65–67
economy: biotechnology in, 80–81; biotechnology for export in, 83–84; centralization and decentralization in, 115–16, 132, 146–47; development of nation-states tied to, 151–52; evolution of, 257; globalization of, 167; in science-culture-economy triangle, 63–65; science integrated with, 208–9; scientific laws applied to, 277; social justice and, 156–58; *see also* knowledge economy
education: in Cuba, 74; in development of nation-states, 152; Municipal University Seat, 107; training as, 105, 106; in universities, 192–94
Einstein, Albert, 277
emergent properties, 59
empirical sciences, 55; *see also* science
erythropoietin, 127
exchange rates and currencies, 271–73
exports: biotechnical, strategy for, 262; biotechnology for, 83–84; of Center for Molecular Immunology

inaugurated, 121–22; in commercial strategies, 224; in Cuban economy, 210–11; diversification of, 175; high-technology companies oriented toward, 250–51; organizations oriented toward, 132–33; research and product development tied to, 207; technological development tied to, 174; of vaccines, 206
extractive industries, 23

Fernández, Fernando Ortiz, 155
financing investments, 252–53
Finlay Vaccine Institute (Cuba), 80, 206
foreign investments, in technology, 182–84, 289–91
Free Trade Area of the Americas (FTAA), 166

GATT (General Agreement on Tariff and Trade) agreements, 31, 46; Trade Related Intellectual Property in, 69
genetics: patents on, 31–32; *see also* biotechnology
German Democratic Republic (GDR), 273
globalization, 38, 167; brain drain linked to, 285; development strategies and, 240; integration of science into economy in, 124; of international trade, 159, 187; of knowledge economy, 160; by multinational corporations, 153; planning for, 254; technology and, 241; of world economy, 142
Global North, 183–84
Global South: brain drain out of, 38–39, 143; cooperation within, 49–50; science in, 177
Guevara, Ernesto (Che), 142, 192; on agonistic capitalism, 37–38; on financial self-management, 146; on managers, 233; on science in Cuban economy, 212; on technology in Soviet Union, 276; on training activities, 106

Haemophilus influenzae vaccine, 269
Hart, Armando, 295
health system, 102–4
Higher Organization of Business Management (Cuba), 216
high-technology companies, 190, 197, 249; direct foreign investments in, 289–91; economic organization of, 217–19; generalizing to non-technical companies from, 256–58; impact of exchange rates and currencies on, 271–73; impact of U.S. blockade of Cuba on, 278–81; leadership in, 260–61; management of, 219–35; nonstate management in, 258–59; origins of, 216–17; *see also* state socialist companies

housing, in Yaguajay, 104
human capital, 75–76, 110, 163–64, 199; in high-technology companies, 229; in universities, 192
Human Genome Sequencing Program, 213
human resources, 47, 91

immigration, brain drain of scientists in, 38–39, 143–44, 284–89
imperialism, 38
Income inequality, 203–4
Industrial Revolution, 34
innovation, 191–92
intellectual property, 30–33, 69, 125–26, 193; Cuban law on, 114; disfunctionality of, 139
International Monetary Fund (IMF), 153, 160
internet, 188
investments: direct foreign investment, 289–91; by state socialist companies, 252––253

joint ventures, 291

King, Martin Luther, Jr., 167
knowledge: attempts to privatize, 164; depreciation of, 52; economically relevant, 85–86; as economic resource, 50–53; fallacy of circulation of, 26–29; impact of U.S. blockade of Cuba on, 280; as intellectual property, 30–33; as product, 109–10; as resource, 24–26; science and culture as forms of, 55–56; science transforms into, 40–41; transformed into value, 88
knowledge economy, 63–64; capitalism and, 68–72; capitalism's clash with, 137–41; cooperation in, 87; in Cuba, 76–78, 242–45; definition of, 22–24; as development opportunity, 239–41; economic organization of, 217–19; as instrument of exclusion, 238–39; intangibles in, 262–65; lacking in Soviet Union and German Democratic Republic, 273–77; in Latin America, 281–84; legal framework for, 265–66; as objective phenomenon, 122–24; opportunities in, 111–17; people in, 267; as political phenomenon, 125–26; socialism and, 109–11, 236–38; socialism and, in Yaguajay, 98–99, 107–9; sovereignty and, 117–19; transition to, in Cuba, 126–29; types of state socialist companies in, 247–53
Kuhn, Thomas, 68

labor productivity, 230
land, 29
Latin America: current social movements in, 293; emigration from, 38–39, 143, 285;

foreign investments in, 290; knowledge economy in, 281–84
leadership, 260–61
Lenin, V. I., 70, 295
Leonardo da Vinci, 56
literacy, 57, 74
Luddites, 34–35
Luxemburg, Rosa, 245

Malaysia, 183
management and managers, 233–34; leadership in, 260–61; non-state, 258–59; in state socialist companies, 251–52
market failures, 90–93
marketing, 225
Martí, José, 21, 57, 71, 168, 281; on Cuban national sovereignty, 155, 156; on science, 63; on social justice, 157, 166; on whole justice, 169
Marx, Karl, 148, 209; on end of capitalism, 42; Guevara on, 37–38; on market failure, 92; on primary accumulation of capital, 32–33; scientific socialism of, 15; on value generated by labor, 25
Mexico, 290
mission statements, 219–21
Molecular Immunology Center, 269
monoclonal antibodies, 121
mortality, 103
motivation, 136; productivity and, 162–63
multinational corporations, 153, 185, 290
municipal government, 106–7
Municipal University Centers (MUCs), 194
Municipal University Seat, 107, 114

NASDAQ, 182, 198, 259
National Center for Scientific Research (NCSR; Cuba), 74, 269
National Institutes of Health (NIH; U.S.), 213
nationality, universality and, in scientific work, 67–68
national sovereignty, *see* sovereignty
nation-states, threats to, 151–54
Negri, Antonio, 126
neoliberalism, 165–66, 168, 203
non-technical state socialist companies, 256–58

painting, 56
patents, 31–32, 69, 185, 264; Cuba's, 51; on intellectual property, 125, 139
peso (Cuban currency), 272
pharmaceutical industry, 27; economies of scale in, 33–34; generalizing from, 257; new drugs produced by, 140; regulation of, 35–36
planning, 253–56
polio vaccine, 36

population, of Cuba, 126–28, 186–87
Porter, Michael, 65
privatization of intellectual property, 125
procedures, 260
processes, 226, 227
production: impact of science on, 198; scientific research integrated into, 99–100
productivity: in biotechnology companies, 207; of labor, 180–82, 230; motivation and, 162–63; scientific, cultural determinants of, 60–63
product line management, 226–27
product line transitions, 226
project directors, 227
projects, 226–27
property, 29–30; intellectual property, 30–33; social property, 115–16

quality management, 228–29

Ramonet, Ignacio, 160
recombinant erythropoietin, 127
regulations, 35–37; as barriers to productivity, 165; for export businesses, 211; to incentivize technological development, 182; as inhibitory, 180; legal framework for, 265–66
research, scientific, 77; as investment, 84–85
research and development: by multinational corporations, 290; spending on, 238–39; strategies for, 224–26
Research Institutes of the Public Health Ministry (Cuba), 74–75
Revolution's Guidelines of Economic and Social Policy (2012), 17, 19
Rio de Janeiro Convention (1992), 53
Rodríguez, José Luis, 145
Rodríguez, Simón, 215

Sader, Emil, 144
science: Castro on, 16, 161, 258; in continuum with culture, 58–59; cultural context of, 54–55; culture and, as forms of knowledge, 55–56; economic development and, 42–44, 75; economies of scale in, 33–35; emergence of profession of, 27; geographical concentration of, 40; integrated with economy, 208–9; nationality and universality in scientific work, 67–68; in science-culture-economy triangle, 63–65; in Soviet Union, 276; transforms into knowledge, 40–41
Science Academy (Soviet Union), 212
Science and Technology Units, 105–6
scientific development, 194–95

scientific method, 56–58, 60–62
Scientific Pole (Havana), 79, 83, 171, 195; creation of, 95–96, 206; exports from, 172, 174, 175; intangible assets in, 263; legal procedures for, 266; merged into BIOCUBAFARMA, 268; organizational structure of, 178–79
scientific productivity: articles published, 188; cultural determinants of, 60–63
scientific research, 77; in Cuba, 178; economic development and, 176–77; financing, 193; integrated into production processes, 99–100; as investment, 84–85
scientific socialism, 15, 277
scientists: brain drains of, 37–40, 47, 125, 143–44, 284–89; in Cuba, 47–48; population of, 267
Singapore, 290
slavery, 29, 155
social capital, 110
socialism: high-tech companies under, 93–95, 190–91; knowledge economy and, 109–11, 236–38; knowledge economy and, in Yaguajay, 98–99; knowledge economy under, 92–93; scientific, 15, 277; state's role in economy under, 212
socialist state high-technology companies, 190, 197; *see also* high-technology companies; state socialist companies
social justice, 156–58, 203–5
social property, 115–16
social revolutions, 200–203
software industry, 23
South Africa, 139
sovereignty, 19, 67; of Cuba, 154–56; knowledge economy and, 117–19; threats to, 151–54
Soviet Union, 15–16; academic environment in, 193; centralized economic management in, 144–45; economic development in, 203; knowledge economy lacking in, 273–77; planning in, 253, 255; science in economy of, 212; socialism in, 251
Special Period, 81, 93, 157, 167; Cuban economy during, 172; damage done by, 18, 142; economic impact of, 286; health system during, 102–3; impact on human capital of, 229
state socialist companies, 195, 199, 200; legal procedures for, 266; non-technical, 256–58; science integrated with economy in, 208–9; social justice and, 203–5; social ownership of means of production in, 212–13; types of, 247–53; *see also* high-technology companies
Stiglitz, Joseph, 160

sugar, 272
sustainable socioeconomic development, 117

technology: absorptive capacity of, 113; foreign investment in, 182–84; high-tech socialist companies, 190–91; management of technological discontinuities, 205–10; planning for development in, 254; in Soviet Union, 276
Third Industrial Revolution, 76
Toffler, Alvin, 22, 65
tourism, 104, 187
Trade Related Intellectual Property (TRIPs), 69
training: in high-technology companies, 230; in Yaguajay (Cuba), 105, 106

United Nations Economic Commission for Latin America and the Caribbean (ECLAC), 281
United States: biotechnology in, 78, 81, 138; brain drain into, 143; economic war against Cuba by, 243; high-tech sector in economy of, 258–59; impact of blockade of Cuba by, 278–81; NASDAQ in, 182; support for scientific research in, 213
Units of Science and Technology (UCTs), 105–6
universality, nationality and, in scientific work, 67–68
universities, 192–94, 214, 267–71
University of Informatic Sciences, 96, 112, 147, 206
USSR, *see* Soviet Union

vaccines, 36; in Cuba, 79–80; exports of, 206; against *Haemophilus influenzae,* 269
value, knowledge transformed into, 88
Venezuela, 84, 183
vision statements, 220–21

wages, 162–63, 261
whole-cycle organization, 130–31
World Trade Organization: on patents, 185

Yaguajay (Cuba), 18; developmental projects in, 105–7; health in, 102–4; knowledge economy and socialism in, 98–100, 107–9